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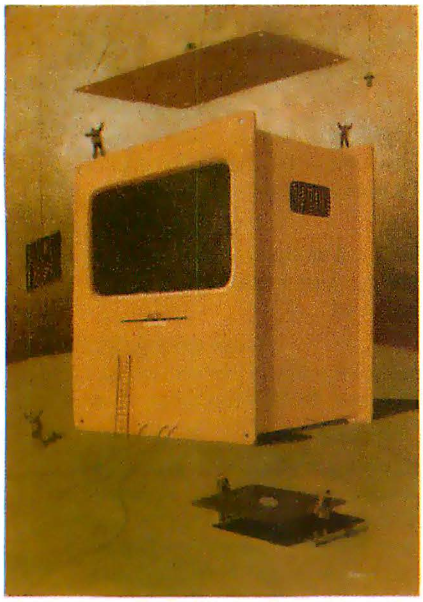
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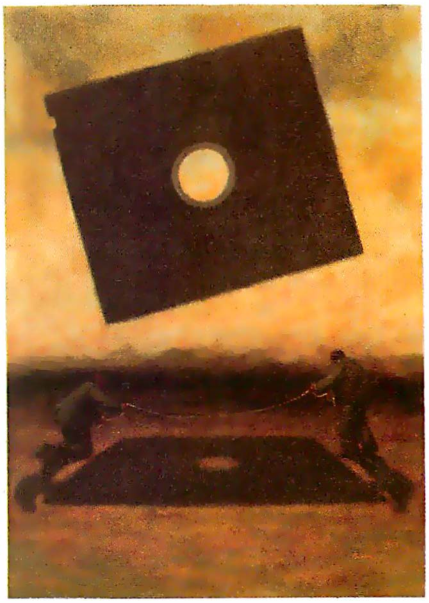
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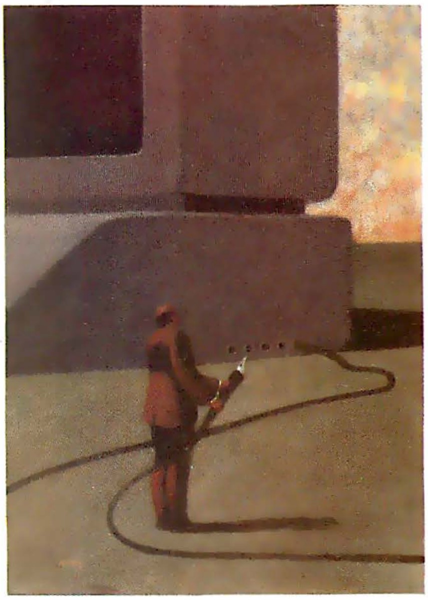
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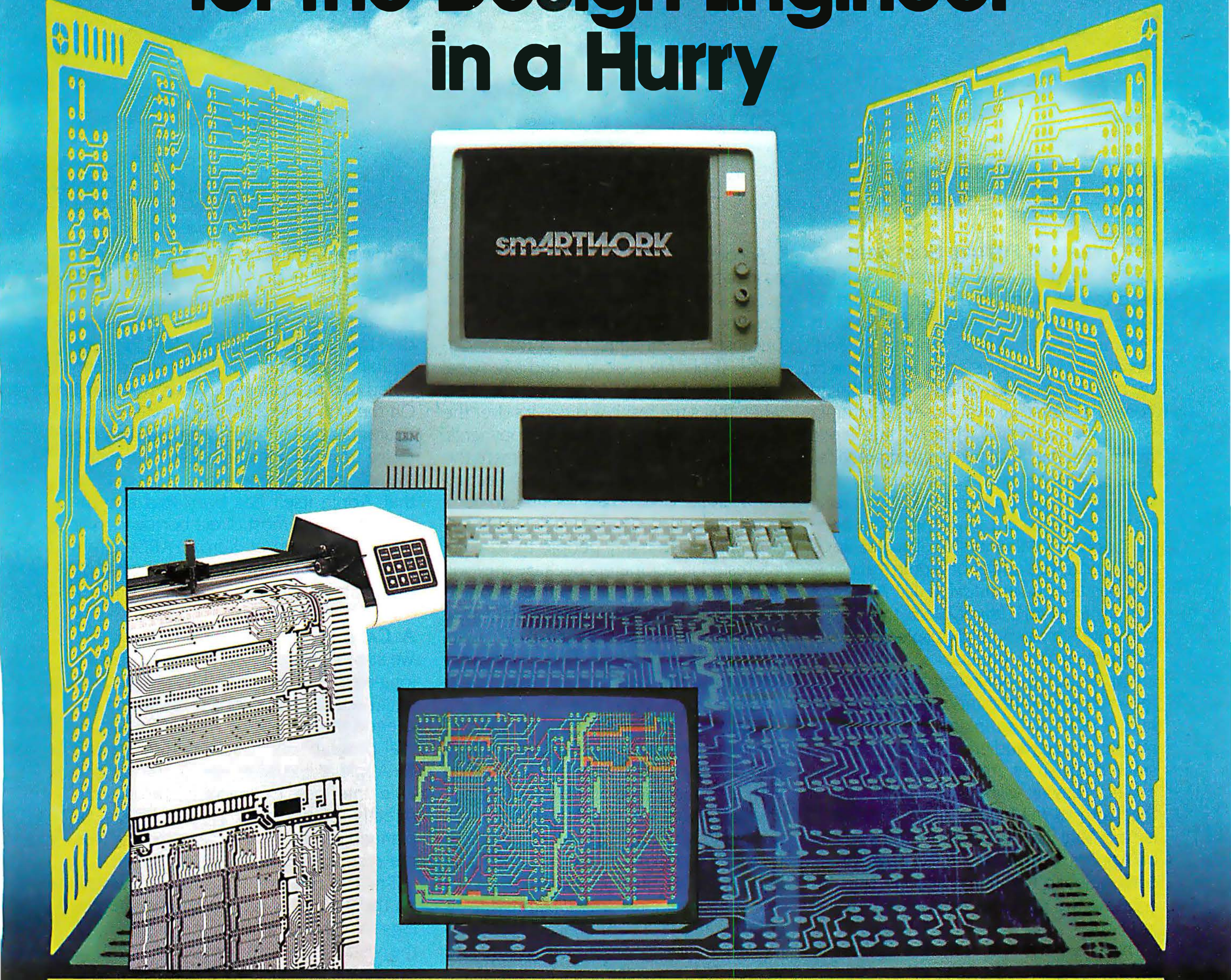
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A Threat to Future Software

Last October Digital Research Inc. yielded to pressure from Apple and agreed to change its GEM software to decrease its resemblance to Apple Macintosh software. (GEM is an operating environment for several MS-DOS– and PC-DOS–based computers that allows a user to interact with a computer via windows and icons rather than the usual text-only commands.) Let's ignore, for the moment, the uncertain worth of a "visual copyright" (the legal term for Apple's copyrighting of the overall "look" of Macintosh software). Let's also ignore the ethics of Apple's actions. *The point to focus on, instead, is that Apple's actions are to no one's benefit*: Both the microcomputer industry and Apple itself will suffer from their effects.

Apple's actions will slow the growth of the microcomputer industry, which will hurt Apple by shrinking the potential microcomputer audience. Already, several small companies are worried that some project they're working on (and, often, they with it) will be cut down because it is "too Mac-like." In addition, the success of Apple's tactics may encourage other companies to try similar actions, thus increasing the paralysis and anxiety in the industry.

These actions will stifle the *incremental evolution* that is at the root of any significant growth in our industry. By "incremental evolution" I mean the process of gradual improvement of a product type that eventually leads to a more robust, useful product. For example, Ashton-Tate's Framework did not spring full-blown from the heads of the programming team at Forefront. It had its roots in Dan Bricklin's and Bob Franston's VisiCalc spreadsheet, Sorcim's Supercalc (which added functions and sold to a market not supported by VisiCalc), Mitch Kapor's VisiPlot (which gave the distinctive highlighted menu bar now used in so many programs), the software integration of Lotus 1-2-3, and the icons, windows, and pull-down menus of—well, you get the point. If companies are afraid to go to market with what they think are incremental—but distinct—improvements on a basic design, we will become a stagnant industry bounded by the usual and comfortable.

According to Irving Rappaport, Apple's associate general counsel, Apple's intent is to prevent other companies from creating products that are easy to use because of their similarity to the Macintosh. "If people look at it and say, 'Gee, that's like the Mac—I can operate that,' when that's the result you get, it's over the line" of infringement of Apple's copyrights. The effect of this intent is to fragment the industry in the face of what was becoming a de facto standard for human-computer interaction. This lack of standardization will cause many people to stay uninterested in computers because they will have to relearn basic skills with each brand of computer they encounter. (Imagine how many people would drive cars if car manufacturers used different controls for every function in the car.)

Apple might argue that, by claiming a larger slice of a smaller pie, it will still come out ahead. We believe that it will be hurt directly by its actions and will end up with a smaller piece of a pie that is itself smaller. Apple will, in effect, build a wall around its ghetto of Macintosh products, thus limiting its own growth and encouraging people to "live" elsewhere.

Texas Instruments' TI-99/4A provides a good example. TI announced that it intended to directly profit from *all* software written for its machine by forcing third-party software developers to publish their products through TI. When a brave few brought out 99/4 cartridges on their own, TI added a proprietary chip to their cartridges that the computer required before it would run the enclosed software. Needless to say, the few developers working on 99/4 software wisely turned to support other computers.

The same may happen to Apple. IBM already sells over half the business computers bought today, and IBM PC-compatibles account for a fairly large slice of what's left. If Apple has been slowing the erosion of its market share to IBM with the Macintosh line (and I think it has), its current moves will alienate software and hardware developers, who will begin to lavish their creativity upon the more congenial IBM PC-compatible marketplace. And where innovation goes, the market will follow.

Consider: IBM made its software and hardware architectures open. It allowed the development of innumerable hardware clones, many far more similar to IBM products than GEM is to the Macintosh desktop; consequently, the IBM PC-compatible market far outdistanced its combined competitors in less than two years. On the other hand, Apple is actively discouraging not only copying but also *borrowing* from its software design. It claims the sole right to benefit from a set of ideas that Apple itself has borrowed and improved on (the most direct borrowing was from work done at Xerox PARC). Given these two opposing directions, what do *you* think will happen?

A Call to Action

We at BYTE call on Apple to recognize the long-term implications of its actions and limit itself to prosecuting cases where the alleged theft is not of "looks" but of actual program code. Barring that, we call on Apple to license its allegedly copyrightable interface to markets that do not directly compete with its current or planned product line—if the licensing fees are reasonable, everyone will profit.

If neither of these things happen, we call on the judicial system to hand down rulings that reflect a strict interpretation of the visual copyright laws—that is, that a product is at fault only if it shows *no* distinguishing characteristics in appearance or operation from the alleged original; this would protect products that show incremental evolution. We also call on the industry to do two things. The first is to stand up to Apple and see the case decided on its legal merits. The second is to develop an alternative graphic interface and allow its wide adoption throughout the non–Apple computer community; in this way, the rest of us can get on with the business of making computers—in general—good enough that everyone will want to use them.

[*Editor's note: Apple maintains that the agreement covers "only three specific products," but one of them is* GEM Desktop, *which defines the overall* GEM *environment. Also, according to Kathleen Dixon of Apple, the agreement includes any custom work* DRI *has done, including the modified* GEM *software that Atari uses in its* 520ST *computer.*] ■

—*Gregg Williams, Senior Technical Editor*

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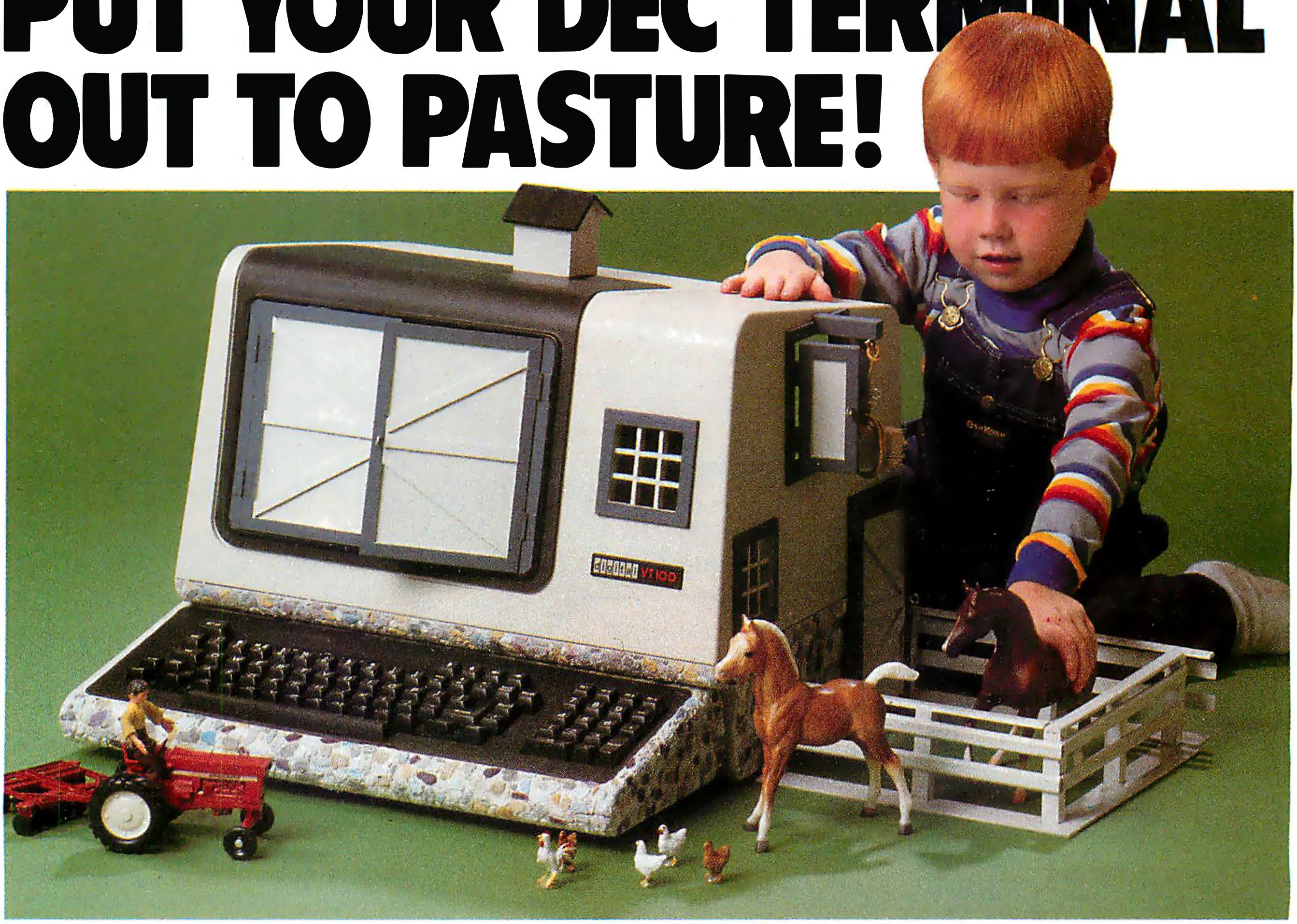
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M·I·C·R·O·B·Y·T·E·S

Staff-written highlights of late developments in the microcomputer industry.

Epson, Toshiba Announce Color LCDs

Toshiba has developed an active-matrix, eight-color, 640- by 480-pixel, 10-inch-diagonal liquid-crystal display (LCD) that nearly matches the brightness of a standard color TV. No pricing or availability information was given.

Epson announced a backlit, high-contrast, 5.13-inch-diagonal color LCD with a resolution of 480 by 440 pixels (one-third of which are red, green, or blue). Epson says the display's contrast ratio is more than 10 times that of a standard reflective LCD and has a viewing angle greater than 60 degrees. Epson also unveiled a high-contrast, 9-inch-diagonal monochrome LCD with a resolution of 640 by 400 pixels. Samples of both displays will be available during the first half of 1986; prices should be approximately twice as much as standard reflective LCDs.

Epson also announced two 10-inch-diagonal monochrome displays using ferroelectric smectic-C crystals. The 640- by 400-pixel and 640- by 200-pixel displays are said to have high contrast ratios, low power consumption, and moderate cost; samples may be available late this year.

Optical-Disk Developments: Write-Once Drives, Partnership

Optimem, which currently makes 12-inch write-once optical-disk drives, showed a prototype multifunction 5½-inch optical-disk drive at COMDEX. The drive will work with read-only, write-once, and erasable disks produced by 3M. Optimem had not yet finalized specifications for the drive but expects to begin shipments in 1986.

Sony announced a new line of write-once optical-disk drives. The WDD-2000 uses a 20-cm (8-inch) optical disk that can store 1 gigabyte of formatted data; a single drive with a controller will have a list price of $16,000. The WDD-3000 uses a 30-cm (12-inch) optical disk to store 2.1 or 3.2 gigabytes of formatted data, depending on the disk used; a single drive with a controller will have a list price of $19,000. Sony also unveiled a jukebox-style device capable of holding 50 of the 12-inch disks.

AGA Inc., New York, NY, introduced an optical-disk system for the IBM PC based on a 12-inch write-once drive from Alcatel-Thomson Gigadisk. AGA says its Discus 1000 stores up to 3 gigabytes of text data or up to 50 gigabytes of graphics images on a 1-gigabyte disk, using a proprietary data-compression technique. The drive alone is available for $21,500; with the data-compression facility, it's $31,000.

Du Pont and N. V. Philips revealed a joint venture to produce optical disks, including 4.7-inch CD-ROM and CD audio disks, a 12-inch write-once disk, and an unspecified erasable disk. The joint venture hopes to produce 200 million disks annually by 1990, half for data storage.

New Developments in 32-bit Chips

Signetics, Sunnyvale, CA, unveiled the 68070, a microprocessor that is compatible with Motorola's 68000 but also includes on-chip memory management and direct memory access. Samples of the 68070 should be available from Signetics and parent company Philips next summer, with production quantities available in late 1986.

National Semiconductor began shipping samples of its 32332 microprocessor, which provides more on-chip functions and memory-addressing capability than the 32032. New on-chip features include dynamic bus-sizing (8-, 16-, or 32-bit data buses), burst-mode memory addressing, a barrel shifter, an expanded instruction queue, and support for external cache memories. The 32332 expands the 32032's 16-megabyte address space to 4 gigabytes by adding a full 32-bit address register. While the 32032 was available only in 6-, 8-, and 10-MHz versions, the 32332 will instead run at 10, 12, or 15 MHz. Weitek Corporation will interface its two-chip, 64-bit, floating-point math coprocessor to the 32332.

The Royal Signals and Radar Establishment, Malvern, England, is developing the Viper, a

(continued)

new 32-bit, RISC (reduced instruction set computer) microprocessor design. Because RSRE wanted a reliable chip for use in weapons and nuclear power plants, the design team used mathematical-correctness techniques that compare a formal specification of the chip with the logical implementation, which they hope will guarantee an error-free architecture and instruction set.

Also in England, a fingerprint-matching computer based on an array of 100 INMOS Transputers is being developed for the Home Office. When finished, the experimental system should run 25 times faster and cost one-fifth as much as the current system, which uses a minicomputer and vector processors.

Vitesse, GigaBit Logic Announce LSI Gallium-Arsenide ICs

Vitesse Electronics will develop gallium-arsenide (GaAs) versions of some Advanced Micro Devices 2900-series devices, which include microprocessors, controllers, and signal-processing chips. AMD currently produces the high-speed parts using silicon bipolar technology; Vitesse expects that the use of LSI GaAs could enhance performance four to six times. Samples of the first components are expected in mid-1986, with full production starting late next year.

Separately, GigaBit Logic announced GaAs multiplexer and demultiplexer (mux/demux) circuits that it says allow fiber-optic data transmission at up to 1.5 gigabits per second (gps), or three times the current limits of silicon. Eight standard 135-megabit-per-second transmissions can be combined in a single 1.1-gps signal. While the mux/demux circuits use about 200 gates per chip, both GigaBit Logic and Vitesse plan to produce GaAs chips with more than 1000 gates in the spring.

Kodak Proposes Tiny Magnetic Disk for Photographs

Eastman Kodak, Rochester, NY, has lined up more than 30 companies—including Sony, Hitachi, and Fuji—to support its 47-mm (1.85-inch) floppy disk for storage of electronic still images. The 800K-byte disk can store up to 50 images of 240-line NTSC video. Eventually, the disk is intended for use in cameras; for now, Kodak is working on a 35-mm film-to-disk transfer station for use in developing labs and a still-video player/recorder for the disks.

Nanobytes

To back up the newer 3½-inch hard disks, **Data Electronics Inc.** and **3M** agreed on a smaller tape-cartridge format that will permit tape backup systems to fit in the same space as a 3½-inch disk drive; drives using earlier ¼-inch tapes required more room. DEI and 3M agreed on two formats: a 120-inch-per-second (ips) 24-track ¼-inch tape that stores 40 megabytes and a 90-ips 12-track tape 0.15 inch wide that stores 20 megabytes. . . . **TDI Software Ltd.** has released a full Modula-2 compiler for **Atari**'s 520ST computer. In England, the compiler is priced at £195. . . . **VMark Computer**, Natick, MA, announced a database-management/application development system that can convert source programs for the Pick operating system to run under **AT&T**'s UNIX System V. . . . **Tall Tree Systems**, Palo Alto, CA, announced the Jlaserprinter, a $400 laser-printer interface for its JRAM-3 memory board for the IBM PC. The Jlaserprinter uses the JRAM-3's expanded memory to allow laser printers like **Hewlett-Packard**'s LaserJet to print high-resolution graphics quickly. . . . **Micron Technology** of Boise, ID, is offering 256K-bit error-correcting DRAM chips. Configured as 64K by 8 bits, the chips cost approximately $6 in quantities of 100. . . . **Novell Inc.**, Orem, UT, announced System Fault Tolerant NetWare software for IBM AT-based LAN file servers, providing three distinct levels of protection from hardware faults. . . . **AST** announced the Shared Resources Network, a new 5-megabit-per-second LAN, which can be made compatible with IBM's PC Network by using AST's NETBIOS software. Each $495 network adapter card comes with a removable ROM chip that allows diskless IBM PCs to be connected to the network. . . . **Integrated Device Technology**, Santa Clara, CA, announced plug-in replacements for **Advanced Micro Devices** 2900 bit-slice processor chips; the Microslice-family chips use from one-third to one-fifth of the power of the AMD chips. . . . **Cermetek Microelectronics**, Sunnyvale, CA, is offering the CH1812A, a DAA component that provides a direct interface to both leased and dial-up phone lines. The DAA conforms to both FCC and Canadian DOC rules and is priced at $18.95 in 1000-piece quantities. . . . **Motorola**'s new 68824 Token Bus Controller (TBC) chip fully implements the ISO Open Systems Interconnect data-link layer for networks; it also conforms to **General Motors** Manufacturing Automation Protocol specifications. . . . **LSI Logic**, Milpitas, CA, announced a CMOS gate array with 50,000 gates made of more than 500,000 transistors.

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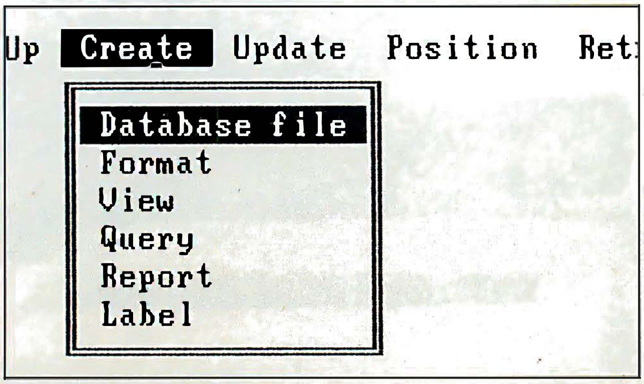
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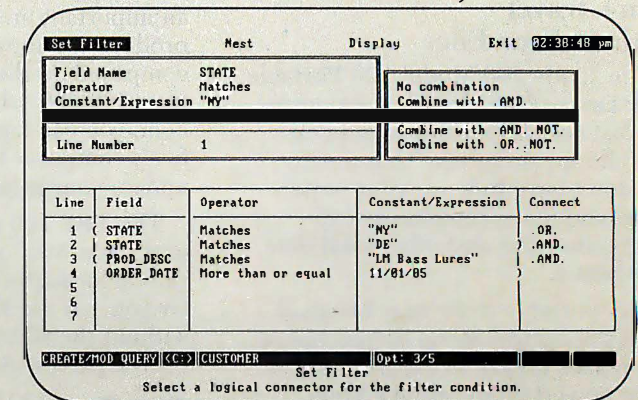
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The Mac and the DSI Sieve Benchmark

As I read the benchmarks in "The DSI-32 Coprocessor Board, Part 1: The Hardware" (August 1985, page 120), I noticed a missing system in the comparisons, the Apple Macintosh. Being a MacUser, I found this disappointing, so I set up and ran the benchmarks on my 512K-byte Mac. My only significant change to the benchmarks used by DSI is the use of a base (pointer) register rather than a global variable for the arrays used. This change allows use of the Mac's ROM memory manager and does not represent a radical change to the routines.

The DSI Sieve benchmark is not fully representative of a machine's Boolean and integer capabilities, calling for only three register variables and using no pointers. Applications written by advanced programmers take better advantage of these tools. Accordingly, I used three versions of Sieve, calling them Sieve (same as the DSI Sieve), RSieve (using more registers), and PSieve (using registers and pointers). The performance of these roughly represents the performance of inexperienced, intermediate, and advanced programmers' code. The Float and FLT benchmarks are transliterations of FORTRAN into C with some assumed register optimizations. See table 1.

All three forms of Sieve beat the IBM PC AT for *n* = 40,000 (and the AT could not run *n* = 80,000). This is due to the much higher costs for 32-bit integer/addressing arithmetic on the AT, needed for addressing large amounts of data and for most applications except games and graphics. Thirty-two-bit integers are standard on the Mac with the SoftWorks compiler. The single-precision Float benchmark for the AT with the 80287 floating-point coprocessor is less than five times faster than the software floating-point coprocessor of the Mac, a surprising result. The hardware advantage of the AT did show up in the FLT benchmark, however. In 64-bit floating-point, the AT's hardware was 12 times faster than the Mac's software.

A quick note on the VAX timings. The VAX C compiler that I am familiar with automatically pointerizes loops such as the Sieve benchmark. PSieve is therefore the equivalent benchmark, and the Mac's speed in this benchmark is near that of the VAX-11/750, particularly impressive since the 750 costs more than 30 times as much. I would like to see the performance of more machines using the multiple Sieve benchmarks since they test a wider spectrum of CPU architectures rather than reducing all to a common denominator.

I have one complaint about the DSI article. It seems to have been written by Definicon Systems Inc., and page 134 reads like a full-page ad for DSI. While the designers may understand the hardware better, I would like to also see an independent review of the system by BYTE.

William L. Hembree
Las Cruces, NM

Table 1: *Reader Hembree's benchmark results for the Macintosh.*

	n	Sieve	RSieve	PSieve
	8191	4.23	3.37	2.80
	20000	10.50	8.37	6.93
	30000	15.87	12.53	10.47
	40000	21.25	16.97	14.00
	80000	43.00	34.33	28.32
Float	(40000)	78.90		
FLT	(256000)	1759.85		

Definicon Systems replies:

We did not think it was fair to include the Mac in the benchmark comparisons because it did not have a hardware floating-point accelerator. Mr. Hembree's own data shows that the Mac is 100 times slower than the DSI in floating-point execution (Float and FLT benchmarks). Floating-point arithmetic is present in virtually all application software, from simple spreadsheets to complex statistical packages.

The Sieve benchmark we used was taken from BYTE. In order to evaluate Mr. Hembree's newer versions, we compiled and ran them. To our surprise, the PSieve version reported an incorrect number of primes. We traced the problem to a double increment of i *in the second* FOR *loop. Without the fix, Mr. Hembree's pointerized version ran in 1.05 seconds on the DSI-32. When the problem was corrected, it took 1.43 seconds. I have*

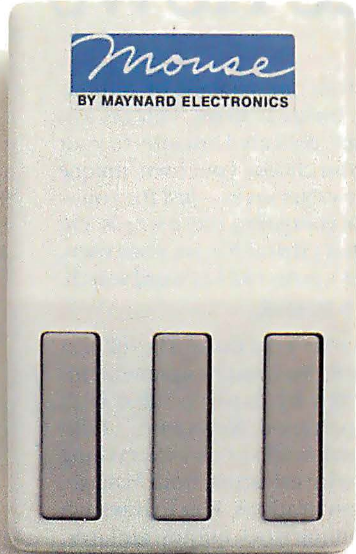
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Table 2: *Definicon benchmark results.*

	n	Sieve	RSieve	PSieve (corrected)	# of Primes
	8191	1.75	1.58	1.43	1899
	20000	4.45	4.23	3.51	4202
	30000	6.70	6.36	5.33	6056
	40000	8.95	8.51	7.08	7836
	80000	17.90	16.81	13.95	14,683
Float	(40000)	0.71			
FLT	(256000)	16.45			

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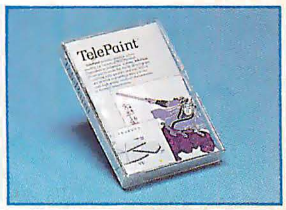
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Adjustable Cursor Speed/Rt, Lft (while running application)	Yes	No	No
Buttons-Definable (while running application)	Yes	No	No
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User-Definable Alternate Cursor Movement	Yes	No	No

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not, as Mr. Hembree did, removed the calls to MALLOC or PRINTF from the times reported for execution.

Table 2 shows the data for the DSI-32 corresponding to Mr. Hembree's benchmarks.

I disagree strongly with the concept that any benchmark or combination of benchmarks can do anything other than show that a particular architecture is competitive with another. For instance, programmer productivity is rarely quantified. We have found, for example, that a 400-line C program takes 15 seconds to compile on the DSI-32, 5 minutes on an Atari 520ST, and 4.3 minutes on a Mac. Why shouldn't this data be relevant when considering a computer's performance? If the VAX compiler automatically pointerizes code and thus makes it run faster, is this not a valid measure of productivity enhancement? Our compiler automatically registers variables. This saves the programmer the task of keeping track of which variables are most efficiently registered. Is this not an important factor in overall productivity?

It really should not matter whether a computer uses a microprocessor from XYZ company or ABC company or whether it performs a sieve in 1.43 seconds or 1.85 seconds. What should be important is what the machine can do for you and how long it takes you to get the machine to do what you want it to.

It is a travesty of objectivity that simplistic benchmarks have become the most widely accepted method for performance evaluation.

The DSI-32 project has so far taken four worker-years to bring to fruition. If BYTE magazine had not become involved, it would be yet another closed-architecture computer accessible only to the inveterate hacker. The technology of 32-bit microcomputer design would still be locked within corporate vaults. BYTE provided a forum for Definicon to promulgate its technology while recognizing that projects such as these will only be made available to the hobbyist while adequate financial return for the development cycle can be maintained.

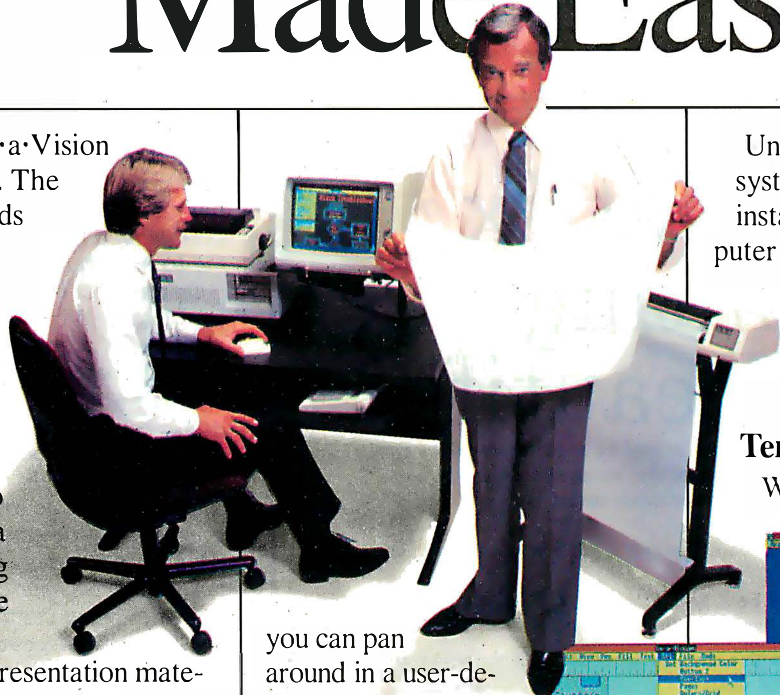
Finally, there was a misprint in the benchmark data published in the August issue. The time for a VAX-11/780 to perform an 8191 Sieve should be 1.09 seconds, not 1.90, as printed.

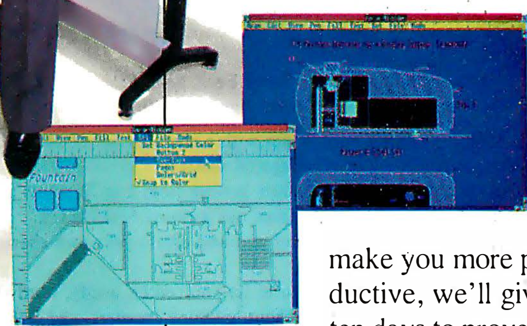
BYTE replies:
Publishing hardware-construction articles presents us with a dilemma. If the author

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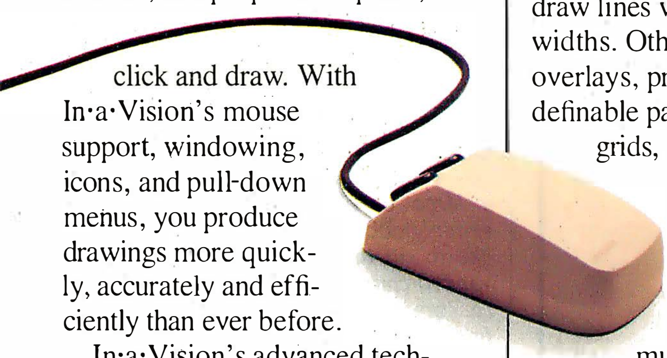




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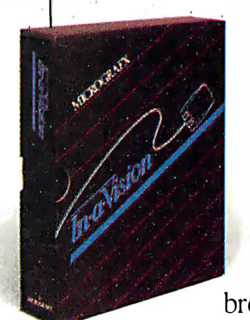
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doesn't support the project by arranging for key parts to be available from one source at reasonable prices and by answering questions of all those readers who build the project, then readers become frustrated and angry. Readers have to go through all the trouble of buying every part in quantity one and at high prices. If the assembled project doesn't work properly, readers rightly want help diagnosing the problem. Supporting 400 readers who have built a project requires time and effort on the part of the designer. Usually the demands far exceed what any individual author is willing to undertake.

On the other hand, when we make certain that a project is backed by the resources of a firm with an adequate staff and that parts and support are easily available, some readers believe that the article is intended to force them to buy a commercial product. This is not the case. Unfortunately, there is never likely to be a charitable foundation that supports hardware-construction projects with design and support engineers, a purchasing manager, clerical help, and all the other resources that go into producing a complex electronic project.

Based on years of experience, we believe that arrangements such as our continuing one with Steve Ciarcia and the DSI-32 agreement with Definicon serve our readers much better than publishing schematics and leaving the reader with no hope of support. Readers who prefer can always work from the schematics and ignore the support firm. BYTE has no financial interest in any of these projects.

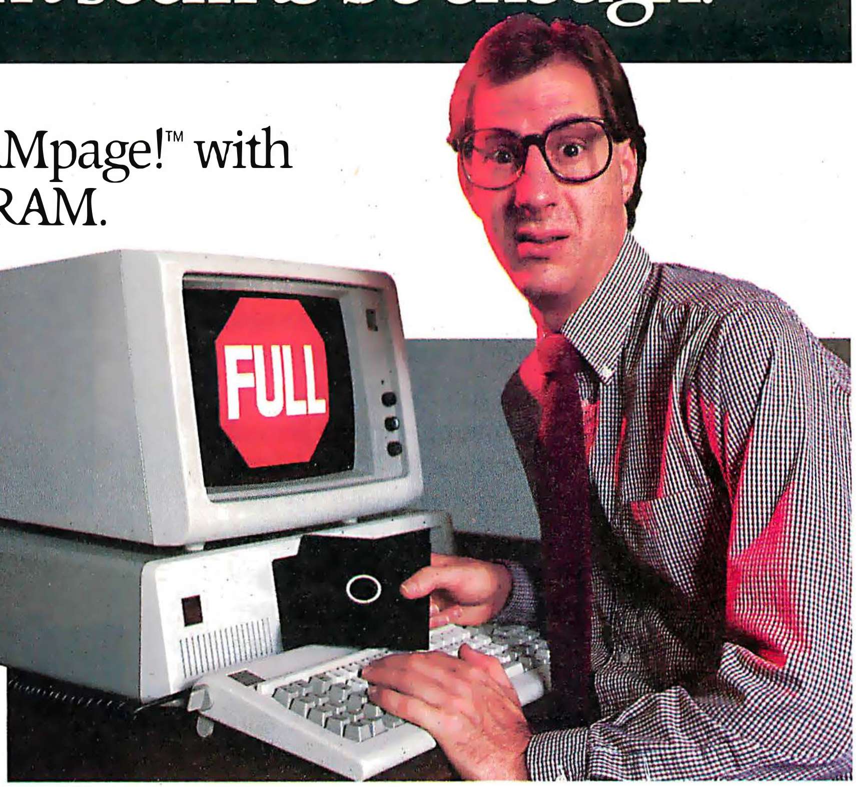
Because our readers' greatest interest is in new technology, we are determined to do hardware-construction articles based on new and advanced chips. Ciarcia's project based on the 64180 and Definicon's based on the 32032 are excellent examples. They afford readers an opportunity to work with systems based on advanced chips without having to buy a large development system from a semiconductor manufacturer. We would like to do more articles based on advanced chips, but we are usually unable to convince anyone to undertake the financial risk and the burden of support. Such articles require purchasing hundreds of parts with no certainty as to how many people will build the project and buy the parts. There are sometimes supply problems with the new parts as well.

We're now trying to make arrange-

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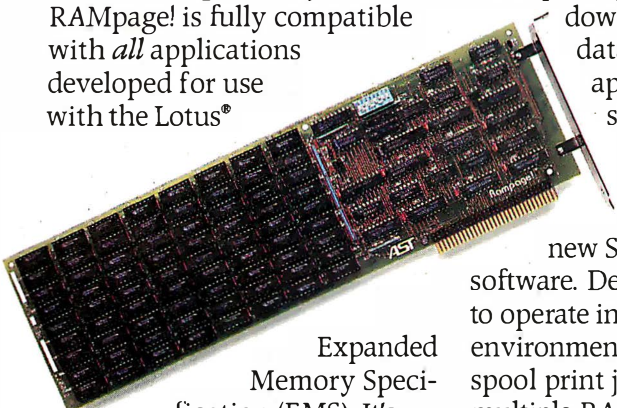
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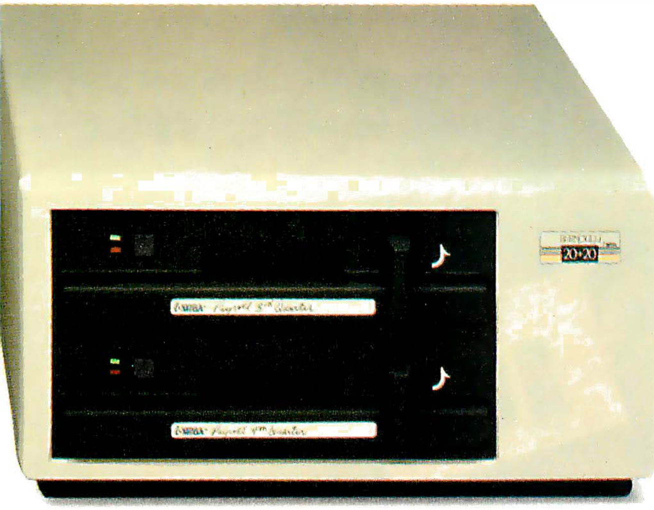
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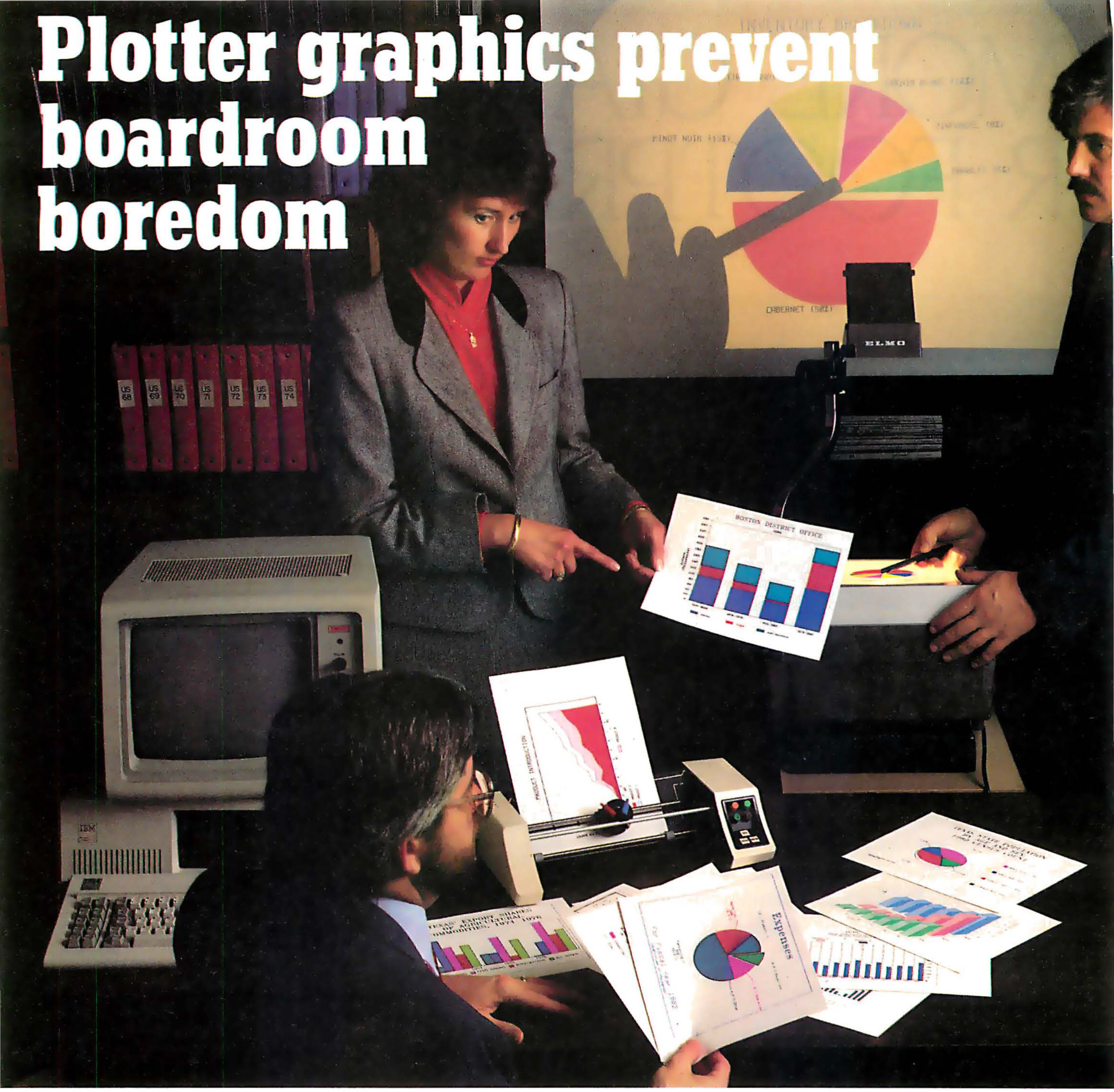
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Inquiry 175

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Inquiry 406 4P019

ments for hardware projects based on three different 32-bit processors: the INMOS Transputer, the Acorn RISC Machine, and the Motorola 68020. Anyone interested should contact Phil Lemmons.

We didn't publish the DSI-32 article without assuring ourselves that the board would work. Phillip Robinson of our West Coast staff saw the DSI-32 assembled and working before we published the article on it. Definicon also shipped us a DSI-32 board that functioned properly in an IBM PC here in our main office. Our technical staff edited the article.

An independent review of the DSI-32 is a good suggestion. We'd prefer to do that as a collaboration among as many DSI-32 users as possible. Those interested should contact Glenn Hartwig.

COMPRESSING DATA

On page 392 of the October 1985 BYTE (Letters), readers found an interesting "printing experiment" that surely could use more explanation. Although it's called a "high-density bar code" in its caption, the sample has little resemblance to a conventional bar code image; rather, it appears to be a direct binary high-density representation of bits framed by an error detection/correction and timing format.

A format like the sample printed has good prospects for delivery of machine-readable data. I count about 64 information bits in width (excluding error detection and framing information), with a density estimated to be 128 bits per inch. The same 128-bpi density seems to be used in the vertical direction, with a length of 7.5 inches. Multiplying the numbers, we can estimate that the test patch represented some 61,440 bits, or about 7.5K bytes. Multiply that by 10 or so columns, and we have an apparent page capacity in excess of 75K bytes. For source code of programs, you'd probably want to use a token-compression scheme. In some experiments I did in 1981 with token-compression techniques, I was able to achieve almost 3:1 compression for large Pascal source programs. Thus, as a means of representing a high-level language program with comments, your 7.5K-byte sample in October could represent the equivalent of over 20K bytes of uncompressed Pascal source text. A 20K-byte source program, while not large, is a significant chunk.

There was another fundamental problem with the bar code formats we printed a long time ago in BYTE. Those bar code formats were ugly to look at. The sample

(continued)

printed in the October 1985 BYTE has information, but at a small enough scale to look reasonably good to the human eye's wonderful power of averaging.

The use of this density represents a significant advance, probably enough to justify purchase of a specialized reader designed like no bar code reader presently on the market. I conjecture that a line-image CCD (charge-coupled device) video sensor could span the width of the image with 128 or 256 pixels relatively inexpensively A brute-force capture device could be made to take advantage of this format provided that it addressed the problem of maintaining alignment during the scan. Rough alignment of the scan with the vertical direction of the page can be provided by the "gutter" of the magazine or a ruler. Vertical timing is obtained from the edges of the pattern as printed. Enough memory to allow processing of several conceptual horizontal lines would allow for a small amount of skew on the part of the line sensor. Averaging adjacent pixels and using a digital threshold test would allow capture of the smallest dots in the format. Vertical timing information present in the format as printed would calibrate the pattern to the actual velocity variations of the person using the device, reducing the need for sampling of the image. Scanning ought to be possible in a few seconds for each chunk of 7.5K bytes or so.

If this technology works, BYTE, its advertisers, and its readers finally have a way of printing recoverable data for source/object code of significant programs, a capacity that was not possible in our earlier experiments with bar code formats. (See my editorial in the April 1980 issue, which summarized BYTE's bar code experiments from 1976 through 1980.) Now, whoever is responsible for this experiment must still answer the entrepreneurial problems: Who will build the bar code readers, and at what cost to the end user? Which comes first, the widespread printing of information or the availability of the readers? By presenting a regular fare of significant programs in source form using this format, BYTE could spawn a whole new marketplace for machine-readable keyless data entry from print.

CARL HELMERS
Peterborough, NH

BYTE replies:
The printed software strip on page 392 of the October 1985 BYTE is called a Cauzin Softstrip. The strip was designed by Cauzin Systems Inc. of Waterbury, Connecticut, and was unveiled at COMDEX last November along with the company's $200 Cauzin Softstrip Reader. Cauzin is promoting the device, which will first be available for the Apple Macintosh and IBM Personal Computers, as a new way of reproducing and distributing programs and data. Robert L. Brass, president of the company, explained the technology behind the Softstrip to me.

The Softstrip can be printed in low-, medium-, or high-density formats. The strip that appeared in BYTE was in medium density and contained about 3000 bytes of information. The standard Softstrip is a bit longer—9.5 inches—and holds approximately 3500 bytes. (High- and low-density strips of the standard size hold 5500 and 500 bytes, respectively.)

(continued)

Inquiry 181 →

PERFORMANCE

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Cauzin's use of a near-infrared sensor in its reader gives the Softstrip some interesting properties. The sensor emits a near-infrared beam of light, which heats the carbon used in black ink and photocopier toner; the receptor portion of the sensor measures the slight heat increase of a dark area. With this method of sensing, you can write with colored inks (or spill coffee, tea, or cola) on a Softstrip and not impair its ability to be read. However, writing across a Softstrip or printing it on multicolored paper is an effective way of copy-protecting it—any attempt to photocopy it will result in extra photocopy toner deposits that will render the Softstrip unreadable.

The Softstrip format was designed to be reliably readable, even in less than ideal conditions. In its medium-density mode, each line of the Softstrip (past the obvious header information at the top) represents 4 bytes (32 bits) of data. Each bit of data is encoded as what Cauzin calls a dibit*—a white square followed by a black represents a 1 bit, and the opposite represents a 0 bit. (Because of this, 4 bytes of data are represented as a line of 64 black and white squares.) Two parity bits are on either end of a line of Softstrip data. A clever scheme of using one bit for parity of the* even *bits and the other for parity of the* odd *bits—plus a checksum on each line and the method of scanning (discussed below)—gives the Softstrip Reader a 1 in 10 billion chance, according to Cauzin, of making an undetected error.*

With an effective accuracy of 0.00001 inch, the scanner scans in increments of 0.0025 inch. In a medium-resolution Softstrip, each line of data is 0.001 inch high; this means that each data line is scanned four times, each in a slightly different place. The sensor integrates the density of each half of the dibit and decides the bit's status based on the multiple versions of this information. Cauzin claims that this method is much more immune to errors than a system that would simply watch for the density transition in the middle of a dibit.

The Cauzin system does not do any data compression, but there are numerous public-domain programs that compress and restore arbitrary files. As Mr. Helmers points out, such compression could effectively double or triple the amount of data that a Softstrip could encode. It is conceivable that a single Softstrip (9.5 by 0.625 inches) holding compressed data could encode as many as five pages of high-level language source code!

Cauzin hopes that its product will become widely accepted and that Softstrips will become a common form of low-cost software storage. We are enthusiastic about the product and wish the company well. We look forward to the day when the Softstrip format is in wide enough use to merit its inclusion in BYTE listings.

INTEL'S BENCHMARKING STRATEGY

There has been a lot of discussion lately (particularly on the UNIX Usenet news network) concerning Intel's recent advertising campaign comparing the Intel 80286

(continued)

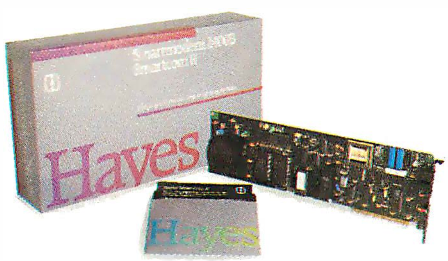


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Moreover, the 2400 is a smart communicator. It communicates with mainframes and minis. Both synchronous and asynchronous transmissions are supported by the Hayes standard command set for 2400 bps. And you can transmit data to another room, or another country because the 2400 meets CCITT international standards.

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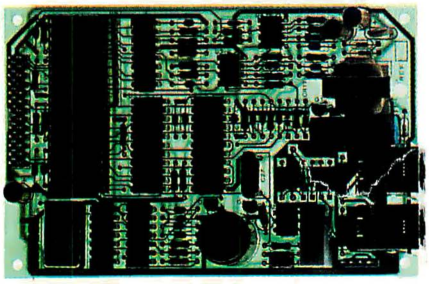
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• Touch tone or pulse • Automatic adaptive phone line equalization • Two-wire lease line capability
• Supports single and multi-line phone systems
• Call progress monitoring

SMARTMODEM 2400B
• Plug-in board for IBM PC packaged with Smartcom II Software • Above features plus synchronous/asynchronous via standard PC communications port • Rear panel communications port switch

SMARTCOM II®
• Menu-driven communications software
• 26 communications sets for automatic log-ons
• Error-free XMODEM and Hayes Verification protocols • VT100/102 and VT52 emulation
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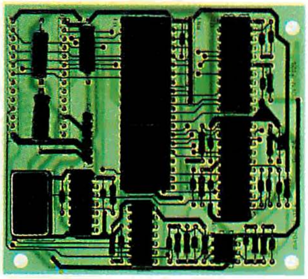
Inquiry 154

When you positively custom



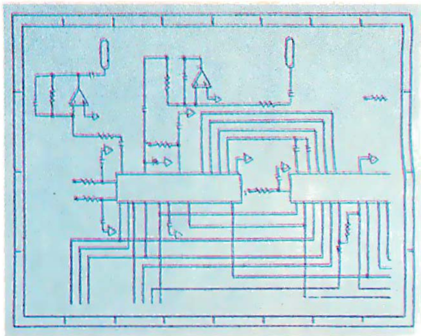
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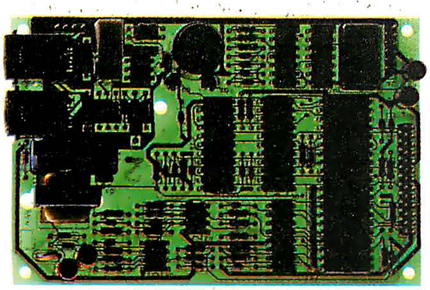
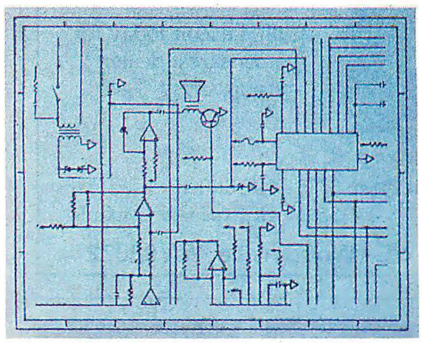
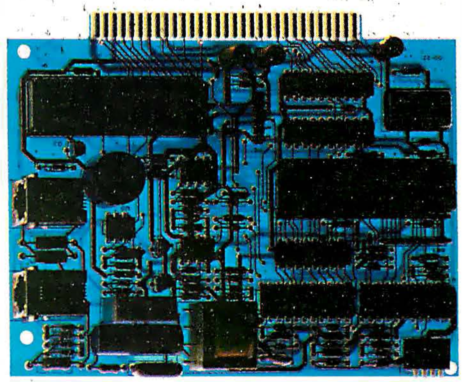
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LETTERS

to the Motorola 68010 and 68020. Intel has published a document entitled "iAPX 286 High Performance Benchmark Report" (hereafter referred to as "the report") to support its claim that the 80286 offers superior performance over the Motorola 68010 and 68020 chips. Both the advertising and the report use the benchmarks that appeared in my article ("Benchmarking UNIX Systems," August 1984 BYTE, page 133) as the basis for comparing the Intel and Motorola chips.

After studying the Intel report, I believe there are several problems with Intel's approach to benchmarking that should be addressed. While the problems presented below may not prove to invalidate Intel's claim, they do raise doubts as to the objectivity and impartiality of Intel's benchmarking strategy. As author of the majority of the benchmarks Intel has used to make its claim, I feel compelled to discuss some problems with Intel's benchmarking strategy.

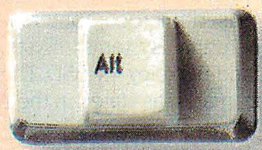
On July 22, 1985, I hand-delivered to the local Intel office a list of problems with its benchmarking strategy and reasons why I believe the company cannot legitimately make the conclusion it did. As of today, I have not received a satisfactory response to most of these issues, which are outlined below.

1. The listing for the pipes.c benchmark as published in Intel's report is incorrect. If this listing is identical to the source code used to evaluate the 80286-based systems mentioned in Intel's report, then the program will terminate prematurely, resulting in invalid timings. This listing is as it was presented in the August 1984 BYTE. However, an error was made on my part when I furnished the listing to BYTE, and a line was inadvertently deleted. I notified BYTE of the omission, and BYTE published a correction in the January 1985 issue (page 14). Intel should have used the corrected benchmark. Intel has responded favorably to this error and has rebenchmarked its systems. I have been told that Intel will publish a correction.

2. Intel admits that the benchmark data used for the Masscomp and Sun Microsystems machines is the data presented in the August 1984 BYTE. The BYTE article was originally slated to appear in the February 1984 issue. Due to production delays, however, it did not appear until August. Although I have no precise record, the benchmark data I gave to BYTE is probably as old as, if not older than, December 1983. This means that Intel is

(continued)

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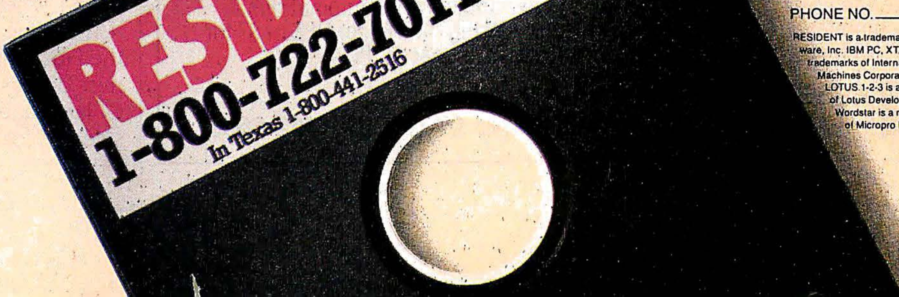
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comparing benchmark results from 68010 machines over a year old to current 80286 benchmarks! Intel apparently did not make an effort to benchmark current 68010 machines other than the AT&T 7300. More recent, but still dated, benchmark data I have shows that the Sun is much faster than reported in at least two benchmarks. Intel should have noted the benchmark dates of the Sun and Masscomp machines clearly as being old and benchmarked current production machines, as it did with the Intel-based microcomputers.

3. The 80286-based microcomputers benchmarked all ran XENIX 3.0. The Motorola-based microcomputers ran different operating systems: System III, System V, and Berkeley 4.1 BSD. The BYTE UNIX benchmarks, as stated in the August 1984 article, are UNIX *operating-system* benchmarks. They are not microprocessor benchmarks and should not have been used as such. The consistently superior results obtained on the microcomputers running XENIX as compared to the microcomputers running other versions of UNIX indicate that performance differences may be due more to differences in operating-system software than to microprocessor design. For example, XENIX 3.0 uses an internal buffer size of 512 bytes; 4.2 BSD uses a 1024-byte buffer size. The pipes.c benchmark as published in BYTE does not take differing buffer sizes into account and assumes a 512-byte buffer size. Read and write operations thus appear to be less efficient on the Sun as compared to other machines. In short, by not taking system differences into account, Intel did not employ the scientific method. Thus, there are too many unknowns for a conclusion to be reached. Intel should have benchmarked a Motorola-based microcomputer running XENIX or an Intel-based microcomputer running something other than XENIX if it wanted to reach conclusions about CPU performance under similar circumstances and operating systems.

On a related issue, Intel's version of the other benchmarks used in the report are flawed, some critically. The company's C translation of the Whetstone benchmark as published has two errors:

1. It is performing one loop more than necessary in module three. This is actually a detriment to Intel's results.
2. The Whetstone uses a single dimension array of four elements. These elements are correctly referenced using the subscripts 0, 1, 2, and 3. Intel's benchmark uses the subscripts 1, 2, 3, and 4.

Intel's version of the Fibonacci recursion benchmark has a more substantial flaw. Because of an extra semicolon, the benchmark makes one iteration instead of the 10 iterations, as implied in the listing.

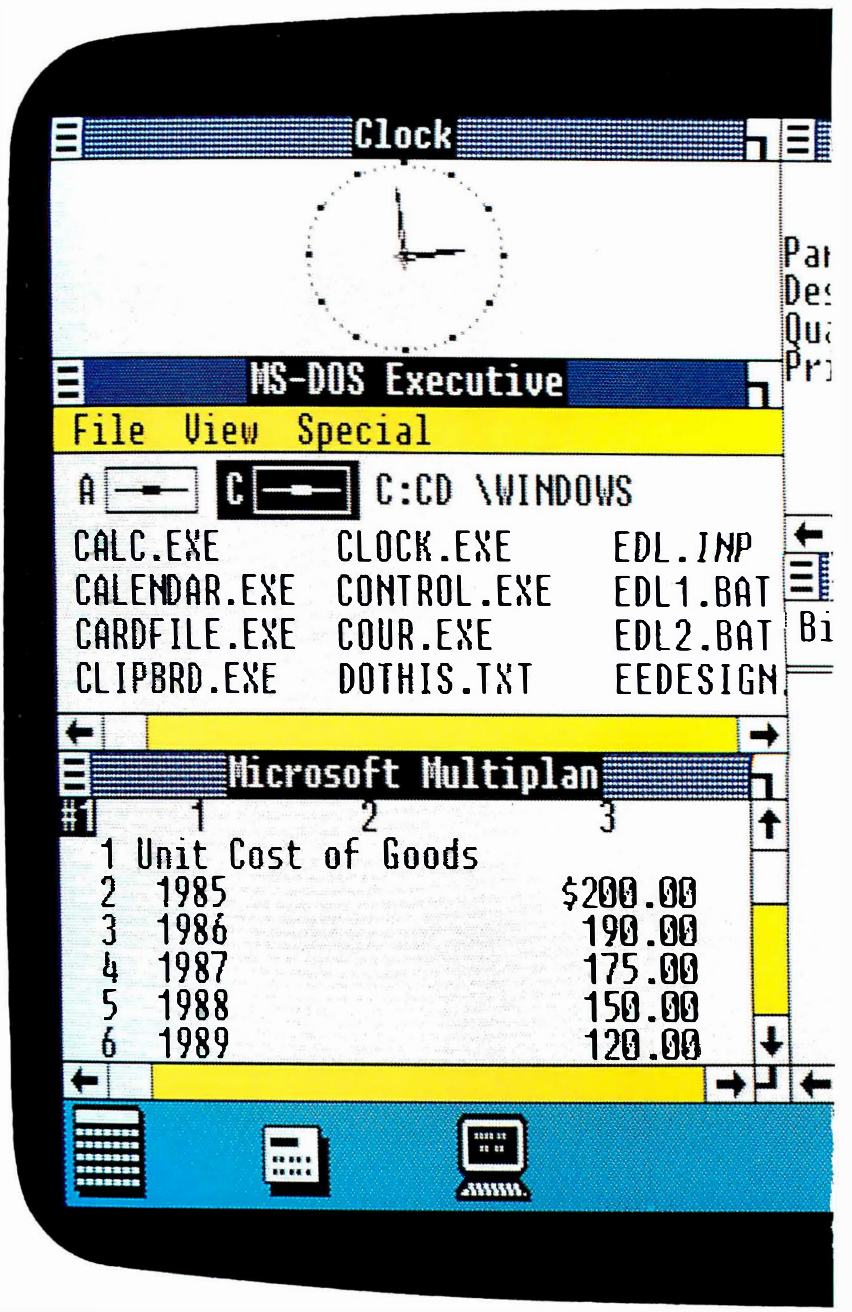
In all likelihood, the errors in the Whetstone benchmark did not significantly affect the results on the machines benchmarked in the report. However, because of these flaws the results from this industry-standard benchmark cannot be compared to data from other versions of the Whetstone.

The same may be true for the errors in the Fibonacci benchmark. Both instances raise doubts as to Intel's knowledge of the C language, which it has specifically selected for comparing microprocessors.

(continued on page 407)

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In short, Windows brings efficiency to all those processes of personal computing which have till now been awkward, unwieldy, inconvenient.

The joys of job hopping.

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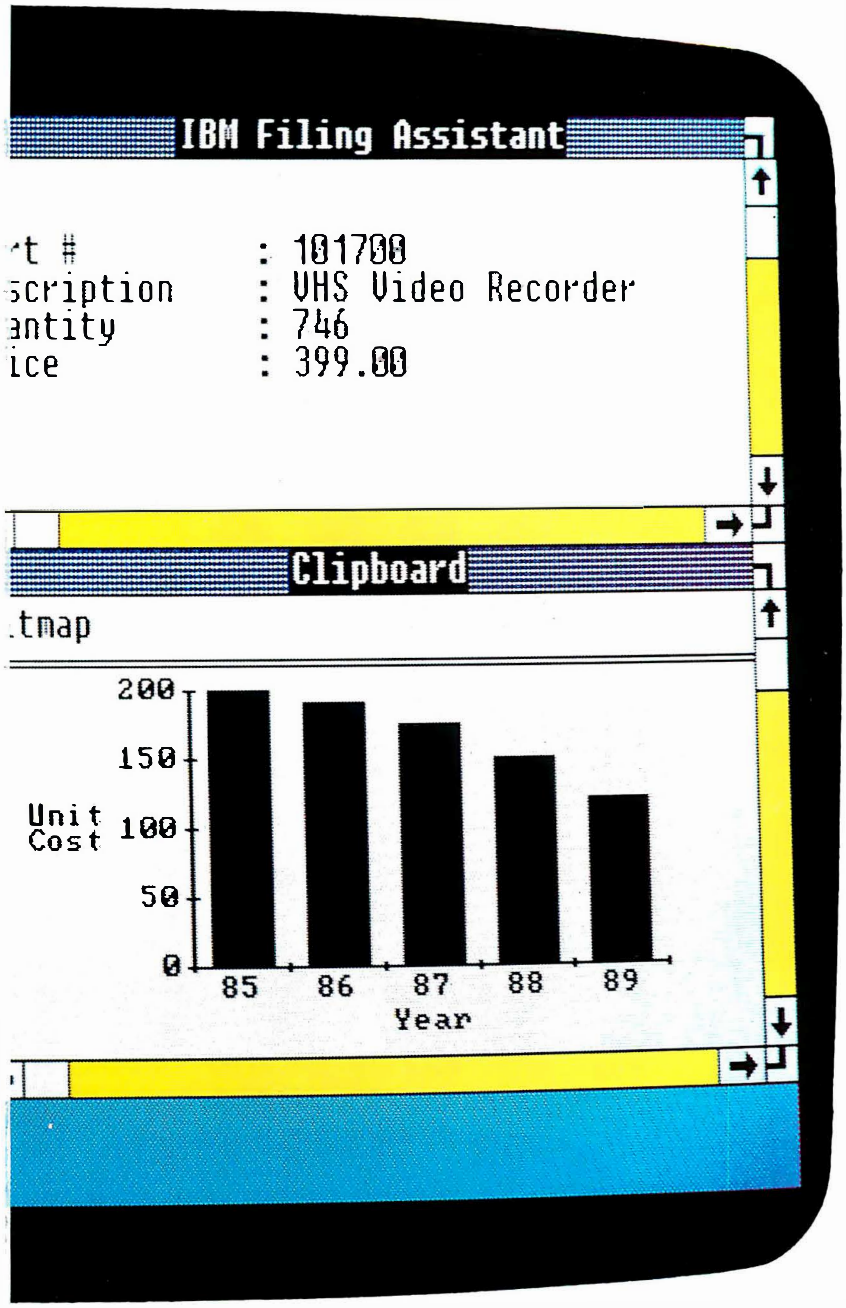
Start up with one application, then another, and another. Leap back and forth between applications as your work routine dictates. Then pick up right where you left off.

The ability of Windows to change quickly from program to program logically and naturally magnifies the utility and productivity of the personal computer. And is a recognition of the way people who exploit the power of PCs really do their jobs.

Breaking the 640K barrier.

Just like you, Microsoft Windows can handle several projects at the same time. Juggle assignments. Deal with frequent interruptions.

And Windows will ignore the 640K limit of your PC, especially if you have a hard disk, the Intel® Above Board, or expanded memory. It will execute the rather neat trick of working with more programs than memory can hold at one time.



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Finally, Windows is not only an immensely powerful tool for today, it's also a solid base for a new generation of Windows applications.

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In Windows applications you have a common interface which includes drop-down menus, dialog boxes, icons. Along with a richer environment that allows you to mix pictures and text. And to summon different type faces and styles at a keystroke.

Windows is a bridge between today's applications and the graphics based software now evolving. A way to work interchangeably with today's programs. And tomorrow's.

If you're somone who uses personal computing as a natural part of your work life, who capitalizes on the productive powers of sophisticated applications, look into Windows, a new vision of what a computer can do.

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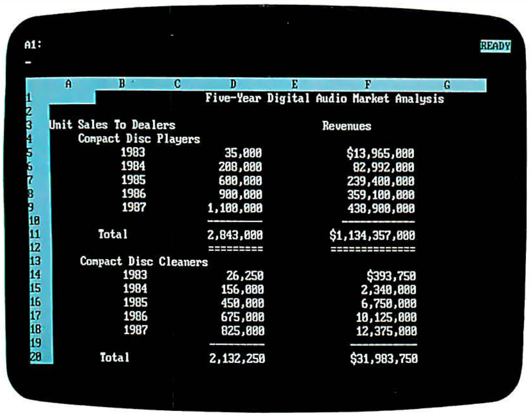
Another great service Windows performs is accelerating the movement of information from one program to another.

Collecting and combining that information is as simple as taking a "snapshot" of data in one program. Editing it. Then consolidating it with data from other programs.

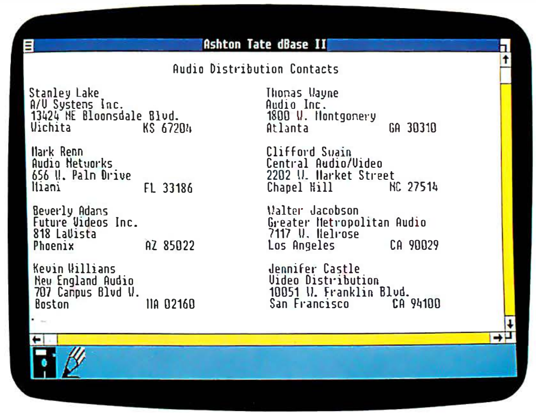
With Windows, you can enjoy the advantages of conventional integrated programs without their compromises. Because Windows lets you put together the applications that you know, and that get a job done for you.

Choose your best word processor, spreadsheet, database—you name it. They're all there for you at a keystroke.

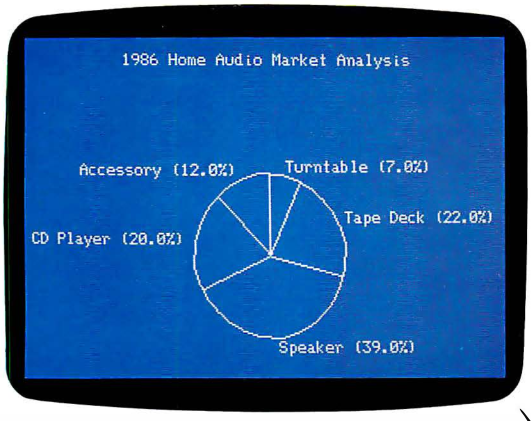
Windows breaks down walls.



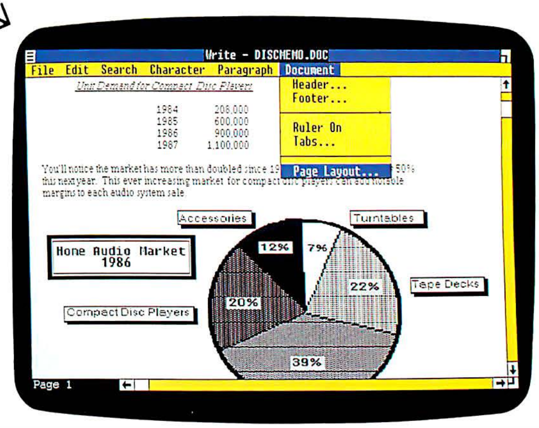
Spreadsheet information from Lotus® 1-2-3® can be captured. And then transferred to Windows Write, our graphic word processing program for consolidating, editing, and formatting.



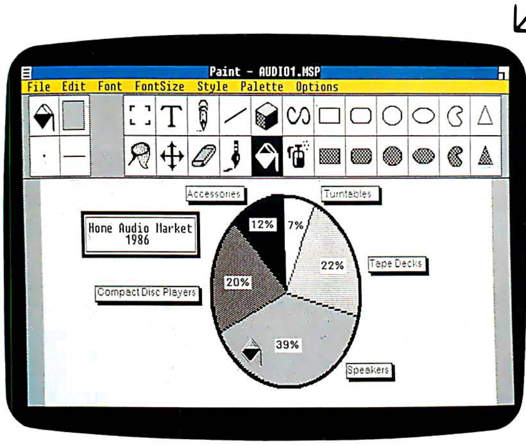
Data from dBASE II® can also be copied and transferred to Write.



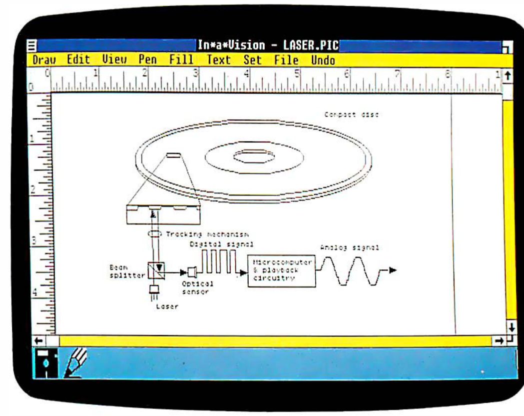
Using your spreadsheet data, build a Lotus chart. Then capture it from the screen. And paste it into Windows Paint.



Windows Write is a straightforward and able word processor. It serves as the "great integrator" in Windows. The place where text and graphics from all your other programs are organized and formatted for presentation. What you see on the screen is what you'll get on the printout.



Windows Paint is an illustrator's studio. A palette of graphic tools. Use Paint to create drawings and diagrams. Or, in this case, to enhance a 1-2-3 chart to emphasize your point.



In-a-Vision, a Windows application by Micrografx, Inc., is a computer-aided design program. Its highly detailed technical illustrations are easily transferred to other Windows applications.

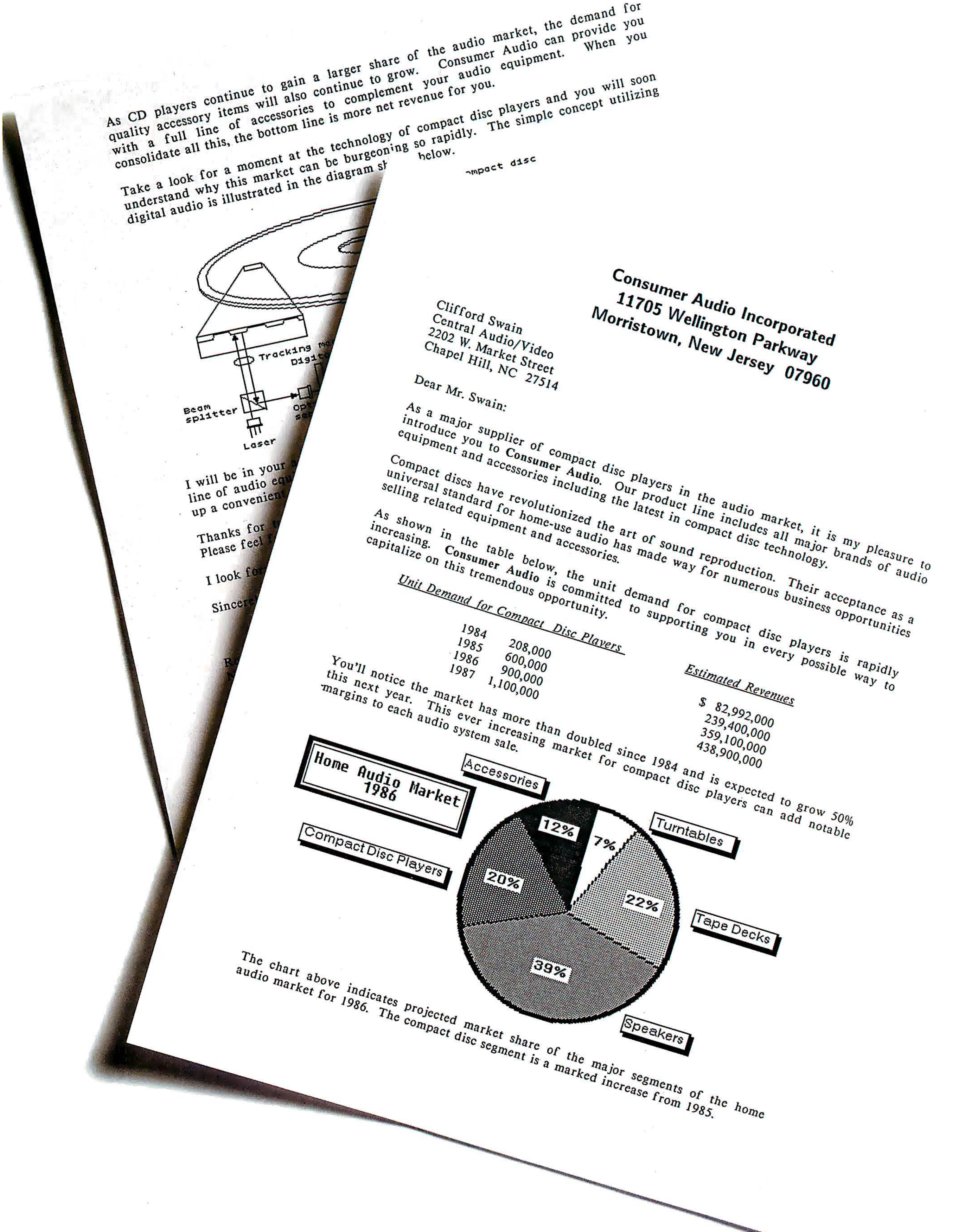
Windows lets you freely combine information from all your applications. And gives you the means to organize, compose, format and print it.

Because Write and Paint are graphic programs, they brilliantly exploit the capabilities of dot matrix and laser printers. When you're satisfied with what you've done in Write, print it.

For a stunning presentation.

Windows provides an easy means of selecting and gathering text and graphics from your programs. And then consolidating it all—text, numbers, and images—in one application.

Windows Write and Windows Paint can serve as a staging area. There you highlight, expand,


As CD players continue to gain a larger share of the audio market, the demand for quality accessory items will also continue to grow. Consumer Audio can provide you with a full line of accessories to complement your audio equipment. When you consolidate all this, the bottom line is more net revenue for you.

Take a look for a moment at the technology of compact disc players and you will soon understand why this market can be burgeoning so rapidly. The simple concept utilizing digital audio is illustrated in the diagram sh... below.

Consumer Audio Incorporated
11705 Wellington Parkway
Morristown, New Jersey 07960

Clifford Swain
Central Audio/Video
2202 W. Market Street
Chapel Hill, NC 27514

Dear Mr. Swain:

As a major supplier of compact disc players in the audio market, it is my pleasure to introduce you to **Consumer Audio.** Our product line includes all major brands of audio equipment and accessories including the latest in compact disc technology.

Compact discs have revolutionized the art of sound reproduction. Their acceptance as a universal standard for home-use audio has made way for numerous business opportunities selling related equipment and accessories.

As shown in the table below, the unit demand for compact disc players is rapidly increasing. **Consumer Audio** is committed to supporting you in every possible way to capitalize on this tremendous opportunity.

Unit Demand for Compact Disc Players		*Estimated Revenues*
1984	208,000	$ 82,992,000
1985	600,000	239,400,000
1986	900,000	359,100,000
1987	1,100,000	438,900,000

You'll notice the market has more than doubled since 1984 and is expected to grow 50% this next year. This ever increasing market for compact disc players can add notable margins to each audio system sale.

The chart above indicates projected market share of the major segments of the home audio market for 1986. The compact disc segment is a marked increase from 1985.

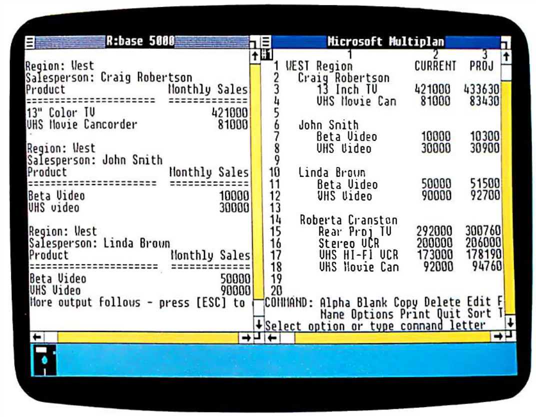
and compose text, charts, and illustrations drawn from a variety of programs. Then format it all for printing.

For instance, you can move data from Lotus 1-2-3 and dBASE II into the Windows Write word processor. A chart from 1-2-3 can likewise be pasted into Paint, a drawing tool. There you have the means to transform a basic chart into something that communicates exactly what you want to say. Which you then transfer to the letter being produced in Write. When you're happy with content and composition, print the page on a graphic printer just as you see it. The better your printer, the better the result.

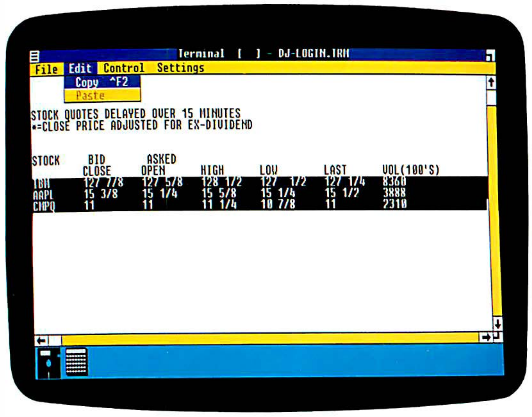
Spend a day with us. You'll



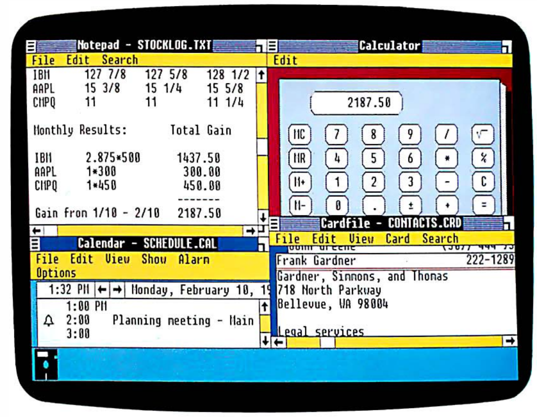
7:45 AM. Early as usual. Opening Windows lands you in the MS-DOS Executive, the Windows command center and file directory. Run the Windows Calendar program and see what's up for the day.



7:55 AM. You've got a report due by the end of the day. A comprehensive sales analysis. Bring up Multiplan® and R:BASE 5000® Copy regional sales data from R:BASE into Multiplan.



1:30 PM. Market's closed. How'd you do? Open Terminal to dial Dow Jones News/Retrieval® and check the final quotes. Copy and paste them into Notepad.



1:45 PM. You did pretty well today. So use the Windows Calculator to figure your gains. Which you duly note in Notepad. Your good luck, however, requires a call to your tax attorney. A quick click brings up his listing in Windows Cardfile. Another click dials him automatically on your modem.

One of the great beauties of Windows is that in the here and now you enjoy the benefits of computing's future path—graphically oriented software. Without giving up any of the applications you're happy with today.

Windows integrates the DOS programs you're already using with a wide array of Windows applications.

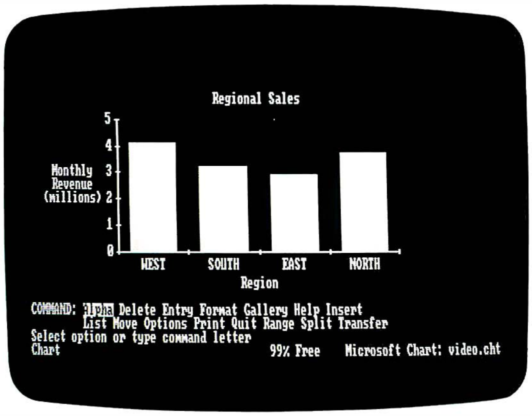
In addition to Windows Write and Paint, the package includes a collection of Windows desktop applications which you can use to manage your day-to-day activities. A calendar, cardfile, notepad, calculator, and telecommunications program, just to name a few. Used together with your standard applications, they can handle an impressive list of office routines.

Spend a day with Windows and the future of business computing falls into place.

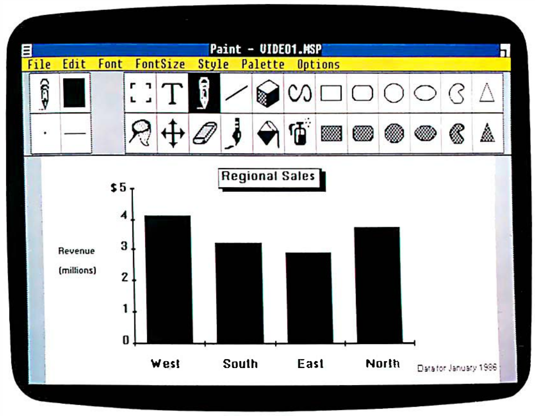
Windows isn't merely an operating environment. It's an extremely useful collection of applications.

And because Windows runs most existing

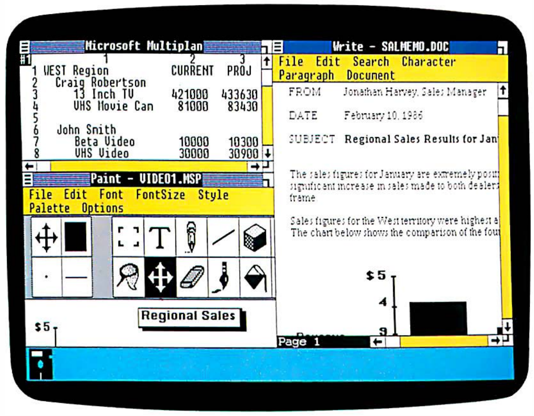
never give up a Windows office.



10:30 AM. You've squeezed everything you can out of the numbers. Now open up Microsoft Chart. And let the pictures tell the story. When you've made a chart fit for presentation, capture it from the screen.

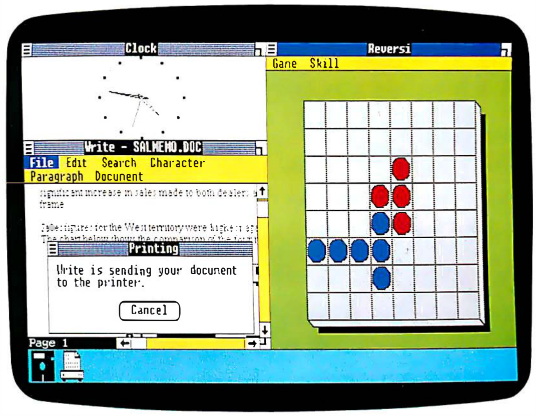


11:00 AM. Paste your finished chart into Windows Paint. Add borders, highlights, and illustrative detail. Not only more appealing, but more effective.



1:55 PM. No sooner do you hang up, than your Calendar alarm sounds. Checking the Calendar, you find you've got a meeting at 2.

3:00 PM. The meeting went on forever. About time you got back to that report. Copy the chart from Paint, and paste it into Write. It looks brilliant. Now write it so it *sounds* brilliant.



4:48 PM. Everything on screen is looking good. You're ready to print. Open Clock to confirm time. That's right, it's tight. Choose the Print command and send the document off to the printer. Open Reversi for a quick game while you wait. While you beat the clock you can try beating the computer.

5:00 PM. Report printed impeccably. Turn it in and shut down for the day. After all, you were in fifteen minutes early.

---

standard DOS applications, it's ready to handle any job you need to do today.

But Windows also represents a foundation for the future.

The Windows interface establishes a common set of command conventions, drop-down menus, dialog boxes, and icons to standardize operations for all forthcoming Windows applications. Which means once you've learned one Windows application, learning the next one will be deja vu, not start from scratch.

Windows Write and Windows Paint are the first examples of programs that embrace the standard.

In-a-Vision, an impressive computer-aided design program by Micrografx, Inc., is another example. Many more are now being written.

And because Windows runs standard DOS applications, you can look forward to the future. But you don't have to wait for it.

The first reviews are in.
Here's what they see in Windows.

Prominent reviewers and industry experts have been eagerly awaiting the arrival of Microsoft Windows.

Now they've had a good look. And we're pleased to record their responses to what they saw.

"I'll bet on Microsoft Windows."
Jonathan Sacks, West Coast editor of *Popular Computing* magazine.

"You've got a clear winner..."
Stewart Alsop, editor and publisher of *P.C. Letter.*

"...Windows looks very good..."
Peter Norton, in his column in *PC Week* 9/24/85.

Of course, all this is going to cost you: $99.

A price that makes Windows the most startling value ever offered in software.

A comparable collection of programs—a switching program, a graphic interface, desktop applications, a word processor, a drawing program—could easily cost hundreds of dollars more.

Windows will instantly deliver you a more productive present. And a leap into the future.

A future which, frankly, we have no interest in keeping exclusive. At this price, it looks to be arriving in a rush.

Integration features:

- Work with multiple applications and switch between them.
- Run more applications than fit in memory at one time.
- Consolidate information from standard DOS and Windows applications.

Applications included:

- MS-DOS Executive—DOS file management program. Run programs; format disks; copy, rename, delete files.
- Calendar—Set appointments with optional alarm reminders; daily or monthly view.
- Cardfile—Filing program; cards can include text or graphics, autodial capability.*
- Notepad—Text scratch pad/editor; time/date stamp option.
- Terminal—Telecommunications program; copy session data to other programs or capture to file; autodial capability.*
- Calculator—Common arithmetic operations, plus square root, percent, and memory.
- Clock—Can be displayed anywhere on the screen.
- Reversi—Strategy game; four levels of play.
- Control Panel—Set time, date, communication ports, colors, add/delete printers.
- Program Information File (PIF) Editor—Create or edit PIF files for standard applications.
- Print Spooler—Print files from Windows applications while running other programs.
- Clipboard—View information copied from applications.
- RAMDrive—Setup memory expansion cards as a RAM disk.

Introductory offer also includes:

- Windows Write—Graphics based word processor.
- Windows Paint—A full-featured drawing program.

*requires a Hayes compatible modem

Windows will open your eyes.

We invite you to visit your Microsoft Dealer and get a screenful of Microsoft Windows. We think you'll agree Windows is clearly a winner.

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F·I·X·E·S AND U·P·D·A·T·E·S

BYTE'S BUGS

Mac C Updated, QSORT Repaired

Consulair Corporation wrote regarding Tim Field's review of five C compilers for the Macintosh (see the November 1985 BYTE, page 275). One of the compilers he evaluated was Consulair's Mac C version 1.7. The company pointed out that Mac C version 4.0 came out in August 1985.

Consulair also noted an error in the QSORT benchmark (listing 7, page 292). Using its own version of a quicksort program, with 16-bit integers, Consulair benchmarked version 4.0, the results of which are shown below (times in seconds). The source code for Consulair's quicksort version is available on BYTEnet Listings; telephone (617) 861-9764.

	Normal	Register	File Size
FRAME	0.10	0.07	13056
POINTER	26.57	15.17	13056
INTMATH	5.05	2.68	13568
SIEVE	6.33	4.40	13056
QSORT	9.47	8.68	13312
FLOAT	289.90	155.90 (extended)	13568
FIB	29.93		13056

Sorry, ha!

Steve Ciarcia built a computer into a Fraggle Rock lunchbox (see the October 1985 Circuit Cellar, page 86). Fraggle Rock is part of the world of Muppets. Mr. Ciarcia's staff dutifully contacted Henson Associates (whose letterhead reads "ha!"), rightful owners of all Muppet likenesses and concepts, and asked for permission to use a photo of said lunchbox. The mavens of Muppetry graciously granted permission.

However, we failed to acknowledge ha!'s granting of permission. We apologize to Henson Associates for this oversight. (Now will you please call off those large nappy creatures we've seen lurking menacingly around the offices?)

Project Not Bug-Free

Several bugs wiggled into Jonathan Amsterdam's "Context-Free Parsing of Arithmetic Expressions" (August 1985 BYTE, page 138). Antonio Salvadori, associate professor of computing and information science at the University of Guelph in Ontario, sent us the following corrections.

On page 142, in the line that begins UNTIL c < >, there should be only one space inside the single quotation marks. Fourteen lines below that, a closing parenthesis is missing from the comment statement.

The variable savedChar should be initialized by savedChar := chr(empty); at the beginning of the main program.

Benchmark Bug

We go back a ways with this one. An error has been found in the Turbo Pascal benchmarks (July 1984 BYTE, page 267). The problem occurs in the Puzzle program (page 274), in a line near the bottom of the second column. The line reads

```
pieceMax[1] := 1+d*+d*d*3;
```

To correct it, insert 0 between the first asterisk and the plus sign.

BYTE'S BITS

A Paper-Tape Kind of Guy

Roberto Denis, a BYTE charter subscriber in Plantation, Florida, decoded some of the punched paper tape running across the page tops of our 10th anniversary issue (September 1985). The message reads: HOPE TO HERE [*sic*] FROM YOU HARD CORE PAPER TAPE PEOPLE ALL THIS TYPING BETTER BE WORTH IT.

Mr. Denis challenges readers who have copies of BYTE's early letterhead, which had paper tape running across the top, to decipher the message. If there is one.

San Francisco's Exploratorium Comes to New York

The staff of the Exploratorium in San Francisco is packing up more than 80 interactive exhibits and heading east, where they'll set up shop at the IBM Gallery of Science and Art in New York City. The exhibition is designed to help people increase their understanding of light, visual perception, and other phenomena of the physical world.

Among the wonders are the "Distorted Room," where people appear to shrink and grow in this room with no right angles, and the "Duck Into Kaleidoscope," which appears to create a crowd when only a few people are actually present.

The exhibit runs from January 31 through April 26. The IBM Gallery of Art and Science is located at 590 Madison Ave., New York, NY 10022, (212) 407-6100.

How To Access and Use BYTEnet Listings

To access BYTEnet Listings, call (617) 861-9764. When you get the carrier tone, enter two or three carriage returns so that our software can determine your operating parameters.

Optimum modem settings are 8 bits, 1 stop bit, and no parity at full duplex, or 7 bits, 1 stop bit, and even parity at half duplex. Acceptable operating speeds are 300 or 1200 bps. At this time, BYTEnet Listings does not support 2400-bps transmissions.

The BYTEnet Listings software itself is menu-driven. Programs may be downloaded using ASCII, Kermit, Tele-Link, and XMODEM protocols.

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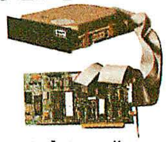
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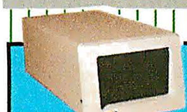
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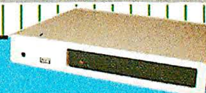


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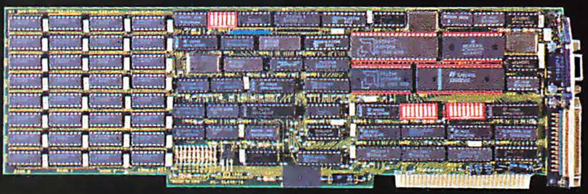
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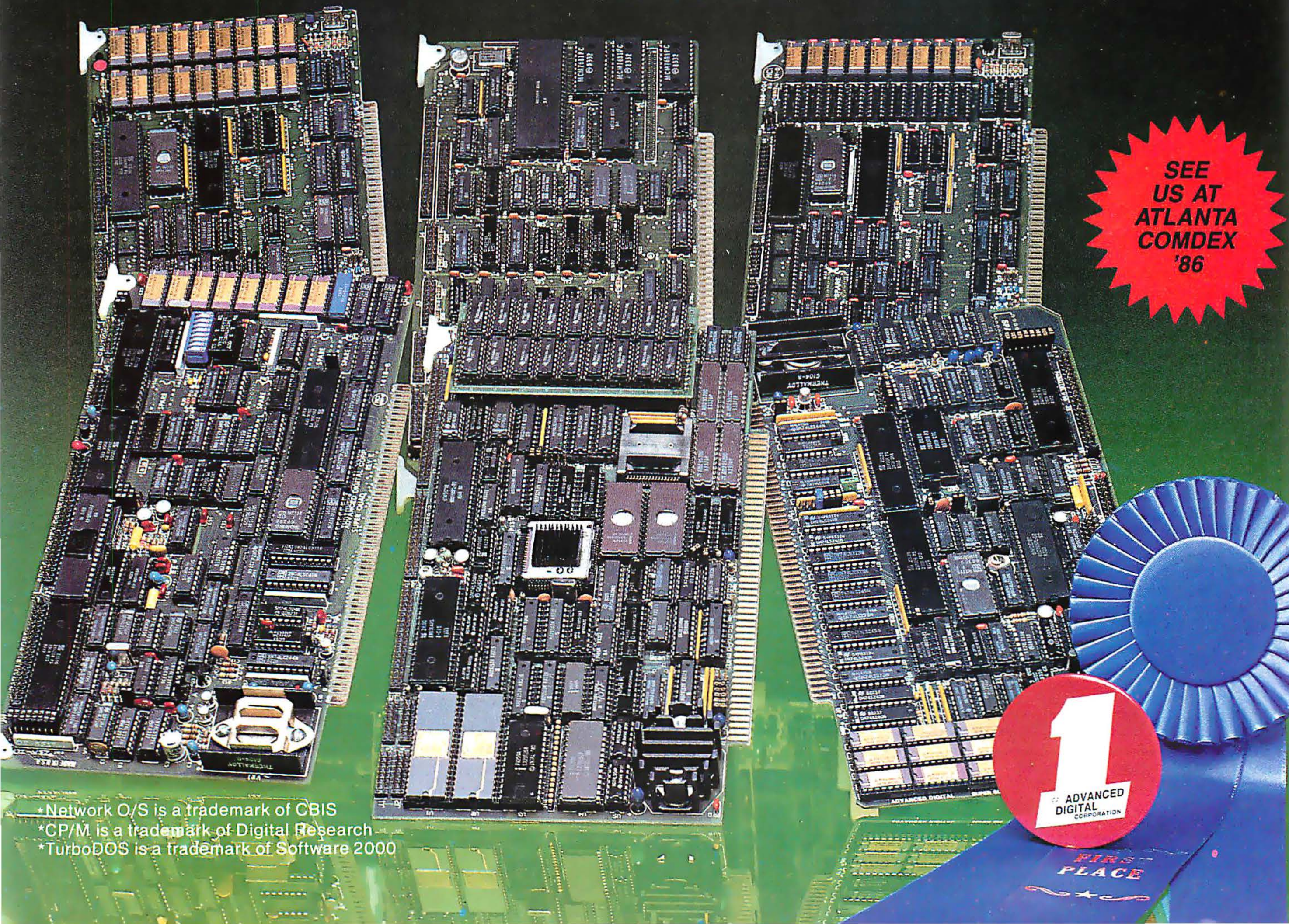
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Hewlett-Packard's Vectra PC.

HP Computer Compatible with IBM PC AT

The Vectra PC from Hewlett-Packard is an 80286-based computer compatible with the IBM PC AT. The Vectra's processor runs at 8 MHz, as opposed to 6 MHz for the AT. A socket is provided for an optional 80287 numeric coprocessor.

The base unit measures 16.7 by 15.4 by 6.3 inches, for a footprint approximately 30 percent smaller than that of the IBM PC AT. Inside, the Vectra PC has five full-size and two half-size expansion slots and room for three stacked disk drives. Drives from either HP or other manufacturers fit into plastic carriers that snap into the chassis, allowing for a wide assortment of mass-storage devices, including 3½-inch and 5¼-inch floppy-disk drives, 20- and 40-megabyte hard disks, and tape backup.

The keyboard has a bank of 10 function keys at the side for use with IBM PC-compatible software; a row of 8 additional function keys across the top provides compatibility with programs for earlier HP personal computers. Theoretically, all 18 keys could be used by a program. The keyboard is connected through the HP-HIL (Hewlett-Packard Human Interface Loop), which allows for multiple input devices without wasting either ports or expansion slots. Both a touchscreen bezel and a mouse are available.

The three basic configurations of the Vectra PC are the Model 25, with 256K bytes of RAM and one 360K-byte floppy-disk drive for $3199; the Model 35, with 256K bytes of RAM and a 1.2-megabyte drive for $3399; and the Model 45, with 640K bytes of RAM and a 1.2-megabyte drive for $3599. A floppy-disk controller is built into the system electronics. Prices include a color-graphics adapter but not a monitor. Prices do not cover MS-DOS 3.1, but if you buy the operating system, you also get HP's Personal Applications Manager. For further information, contact Hewlett-Packard Co., 1801 Embarcadero Rd., Palo Alto, CA 94304, (800) 367-4772.
Inquiry **550.**

Memory-Resident Utilities for CP/M

Spectre Technologies' Presto! is a memory-resident pop-up utility program providing notepad, calendar, calculator, print-screen, and cut-and-paste functions for CP/M computers. Depending on the modules used, Presto! occupies from 6K to 12K bytes of RAM.

The notepad module creates an 11-line by 80-character window for editing or viewing files; to conserve memory, only the current 11 lines are stored in memory, with the rest of the file stored on disk. The notepad uses standard WordStar commands.

The calculator emulates a standard four-function memory calculator. To those capabilities it adds Boolean operators and support for binary, octal, decimal, and hexadecimal math as well as a character mode. A time pad provides a calendar and, on machines with a real-time clock, an alarm and timer. You can print the current text screen to a printer or a file in ASCII format, or you can save a graphics image to a file for later processing with Spectre's Rembrandt graphics program, which is available separately.

Presto! is initially available for the Osborne 1, Executive, and Vixen, and all Kaypro CP/M computers. Spectre plans to release versions for other popular CP/M computers soon.

List price of Presto! is $39.95. Contact Spectre Technologies, 22458 Ventura Blvd., Suite E, Woodland Hills, CA 91364, (818) 716-1655.
Inquiry **551.**

Animation Generator for 64K Machines

Fantavision is a special effects/animation generator designed to help you create animated sequences with 64K-byte Apple IIs. Brøderbund says that with the software, you can produce studio-quality work.

Fantavision incorporates computer animation techniques such as tweening (the machine creates fluid-looking motion by instantly generating as many as 64 intermediate positions between objects) and transformation (an object in one frame can be transformed into a different object in the

(continued)

subsequent frame). You can superimpose special effects onto high-resolution backgrounds available on the program disk or taken from other Apple graphics software. Sequences can be stored on disk.

Fantavision costs $49.95. Contact Brøderbund Software, 17 Paul Dr., San Rafael, CA 94903, (415) 479-1170.
Inquiry **552.**

Add 320K to IBM PC

The IPC 320 RAM board gives you 320K bytes of CMOS RAM with battery backup on a standard IBM PC expansion card. You can divide the 320K bytes into bank-selectable 64K-byte blocks or address the extra memory as 320K bytes of contiguous storage space.

You can install as many as four boards in one IBM PC. If the card is used as a nonvolatile RAM disk, the PC can still address a full 640K bytes of main memory in addition to the 320K-byte RAM disk.

The IPC 320 is priced at $795, which includes RAM-disk software. Contact Diversified Technology Inc., POB 748, Ridgeland, MS 39158, (601) 856-4121.
Inquiry **553.**

Mouse Needs No External Power Supply

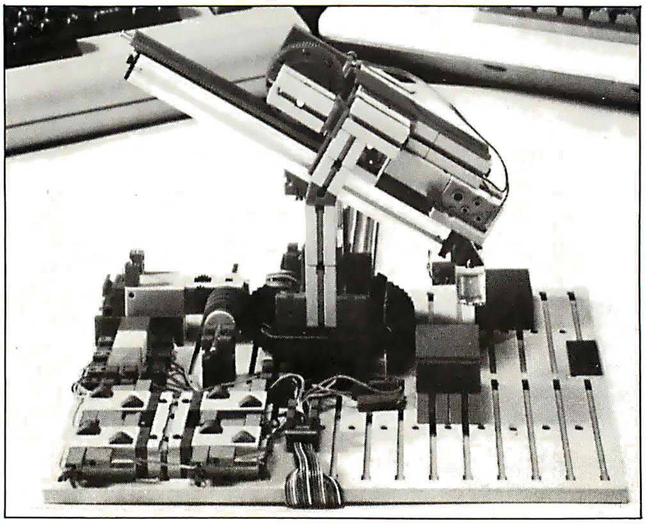


Logitech's Logimouse C7.

Logitech's Logimouse C7 is a CMOS mouse that uses a maximum of 5 mA of electric current. This low power requirement means the mouse does not need an external power supply; instead it runs on power from the RTS and DTR control lines of the host system's serial port. It has a voltage tolerance of 6 to 15 volts, so it can be used with most computer systems.

The standard C7 comes with a resolution of 200 dots per inch (a 320-dpi version is also available) and a programmable data-transmission rate of up to 9600 bps. You can buy it with either a 25-pin RS-232C connector for the IBM PC, XT, and compatibles or a 9-pin serial connector compatible with the IBM PC AT. Logitech will also customize connectors.

Logitech says the Logimouse C7 is protocol-compatible with all existing serial mice and will run with most software packages. It costs $99. Contact Logitech Inc., 805 Veterans Blvd., Redwood City, CA 94063, (415) 365-9852.
Inquiry **554.**


Robotic Computing Kit from Parsec Research.

PortaFile Puts Handle on 20 Megabytes

The PortaFile 20 incorporates a 20-megabyte external hard disk and power supply shock-mounted in a portable case with a carry handle. Packaged with the drive is an IBM PC hard-disk–controller expansion card (which can work with one internal hard disk as well as the PortaFile) and cable.

The PortaFile 20 is scheduled to be available in February for $1295. For additional information, contact Western Digital, 2445 McCabe Way, Irvine, CA 92714, (714) 863-0102.
Inquiry **555.**

Robotic Computing Kit

Parsec Research has taken a robot construction kit made by fischertechnik of Germany and equipped it with a FORTH-based control language called PaRCL (pronounced "parkul"). The kit contains 10 projects designed to teach you the fundamentals of robotics while you build a plotter, sorting system, or other automated devices.

The fischertechnik package (249 pieces in all) comes with two motors, two gears, one electromagnet, three lamps, eight pushbuttons, and two potentiometers. The computer interface has four outputs for connection of motors and other components, eight digital inputs, two analog inputs, and a program disk.

PaRCL is modeled after advanced industrial and laboratory standards. Parsec said the language uses no complex codes; commands are written in English. The routines reportedly run much faster than BASIC equivalents.

After you've constructed your device, you can control it with an Apple II, Commodore VIC-20, or Commodore 64. Besides a plotter and sorting system, other projects in the kit let you build a materials lift, an aerial rotor, a graphics panel, and a teachable robot.

The Robotic Computing Kit sells for $199. The plastic pieces snap together, so assembly requires just a screwdriver. To power the models, you need a 6- to 10-volt DC supply with a minimum of 500 milliamps. Contact Parsec Research, Drawer 1766, Fremont, CA 94538, (800) 633-6335; in California, (415) 651-3160.
Inquiry **556.**

(continued)

NEW FROM BORLAND

Borland Introduces Reflex, The Greatest Analytical Tool Since The Couch

INTRODUCING REFLEX, THE ANALYST.

If you use Lotus 1-2-3™, dBASE® or PFS File™, you need Reflex™—because it's a totally new way to look at your data. It shows you patterns, relationships and interrelationships you didn't know were there, because they were hidden in data and numbers.

Reflex is the first database that separates the trees from the forest. The first database that understands that what you see depends on how you look at it.

The first database that probes relationships—then shows them to you in various graphic forms—scatter, line, bar, stacked bar and pie charts.

The first database to break the bonds of traditional DBMS (Data Base Management Systems) and give a dramatic visual turn to data analysis.

Reflex makes graphic leaps far beyond 1-2-3. With Reflex, when you look, you see.

HOW THE CRITICS REACT TO REFLEX

"The next generation of software has officially arrived."

Peter Norton, PC Week

"Reflex is one of the most powerful database programs on the market; its multiple views, interactive windows and graphics, great report writer, pull-down menus and cross tabulation make this one of the best programs we have seen in a long time...The program is easy to use and not intimidating to the novice...Reflex not only handles the usual database functions such as sorting and searching, but also "what-if" and statistical analysis...it can create interactive graphics with the graphics module. The separate report module is one of the best we've ever seen."

Marc Stern, InfoWorld

"What you see, then, is an interesting hybrid of a database and a spreadsheet that is ideal for analyzing tabular data."

Adam B. Green, InfoWorld

"More flexible than spreadsheets, this easy-to-use database analysis package presents information with visual clarity...Reflex is for you. The flexibility of switching between different views of the data lets you see relationships you may have previously overlooked...Without "what-if" analysis, key variables—such as cost of goods sold or travel expenses—may be out of hand but unnoticed. The type of analysis to uncover such a foible is awkward to do on a spreadsheet; yet, it may mean the difference between success and failure in a competitive situation."

Ira H. Krakow, Business Computer Systems

REFLEX OPENS MULTIPLE WINDOWS WITH NEW VIEWS AND GRAPHIC INSIGHTS.

You use Reflex's Form View to build your database; the List View lets you put data in tabular List form; the Graph View gives you instant interactive graphic representations; the CrossTab View gives you amazing "cross-referenced" pictures of the links and relationships hidden in your data. Report View allows you to import and export data to and from Reflex, 1-2-3, dBASE, PFS File and other applications and prints out information in the formats you want. In fact, Report View is probably the best 1-2-3 report generator you can buy today. It's also the cheapest—and you're getting all the other features free.

The commands for all five Views are consistent—so you're not stuck learning five different ways to get something done. And because Reflex uses advanced windowing techniques, you can see several views on the screen at the same time—without having to switch back and forth. You get the picture—and the pictures—all at once—if that's the way you want to look at things.

Modify a number and all your Views—List, Form and Graph—are immediately updated, on-screen. Changing a number changes the picture—which is mighty handy when you're analyzing (let's say) sales figures by salesperson; or you're in "What-If?" country asking yourself "What if we could add 2.5% in January sales?" "Show me."

"Give me the picture." "Show me what happens when we shift 11% of Nebraska's inventory to the new store in Hawaii." "Show me how many Gizmo 28's we have in every store in every state as of midnight last night and what happens to our East Coast stocks if the shipping strike lasts more than a week." "Show me."

So Reflex shows you. Instant answers. Instant pictures. Instant analysis. Instant understanding.

HOW IN THE WORLD CAN BORLAND SELL A PHENOMENAL PRODUCT LIKE REFLEX FOR ONLY $99.95?

At $495.00, Analytica's original price, Reflex was a bargain. Acclaimed by critics and praised by users, Reflex also got our attention at Borland International. We were so impressed by Reflex that we bought the company!

To celebrate that, we're making business software history by offering Reflex—FOR A LIMITED TIME—for ONLY $99.95! (Offer good through March 31, 1986).

That's $395.05 off the original price—which is a pretty good return on your toll-free phone call.

We think Reflex should be an "automatic product," a "standard" that every PC owner should own. That's why we priced it at $99.95. Naturally we've added our 60-day money-back guarantee and Borland's Reflex is not copy-protected.

NOT COPY-PROTECTED

REFLEX™ THE ANALYST™

To order by Credit Card call (800) 255-8008, CA (800) 742-1133.
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YES! Rush Reflex to me.
Send me _____ copies.

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This price includes shipping to all U.S. cities. All foreign orders add $10 per product ordered.

System requirements.
IBM® PC, XT, AT and compatibles. 384K RAM minimum. IBM Color Graphics Adapter®, Hercules Monochrome Graphics Card™, or equivalent. PC DOS® 2.0 or greater. Hard disk and mouse optional.

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Phone (408) 438-8400 Telex 172373

Inquiry 40 for End-Users.
Inquiry 41 for DEALERS ONLY.

32-bit Floating-Point Processor

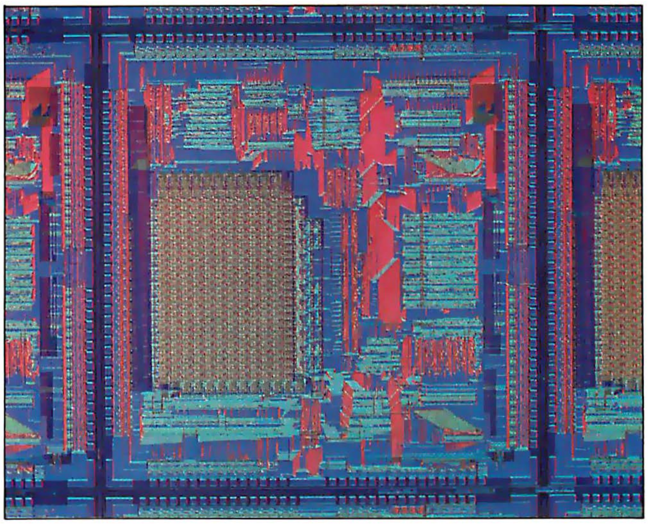
Advanced Micro Devices has developed a single-chip floating-point processor (FPP) that can perform 32-bit floating-point addition, subtraction, or multiplication within a single 150-nanosecond clock cycle. The Am29325 FPP has a flow-through architecture that features two 32-bit input buses and one 32-bit output bus.

This FPP is the first member of the planned Am29300 family of 32-bit bipolar microprocessors. It can perform a single-precision floating-point operation within 150 ns in the flow-through mode or 135 ns in the clocked mode. The chip can be employed in systems based on other microprocessors.

The Am29325 can perform arithmetic using either the IEEE floating-point standard P754 or the DEC single-precision floating-point format. It can also convert numbers between the IEEE and DEC formats and between 32-bit integer and floating-point formats.

In addition to the standard I/O configuration already described, the Am29325 can be selected for a 32-bit, two-bus architecture or a 16-bit, three-bus structure for use with 16-bit microprocessors. The input and output registers can be made transparent so the system designer can use external registers with no system speed penalty.

The Am29325 FPP comes in a 144-pin pin-grid-array package and is priced at $695 each in 100-unit quantities. Contact Advanced Micro Devices Inc., 901 Thompson Place, POB 3453, Sunnyvale, CA 94088, (408) 732-2400.
Inquiry 557.



The Am29325 floating-point processor from Advanced Micro Devices.

Low-Cost Word Processor

DAC Software's DAC Easy Word runs on the IBM Personal Computer and compatible machines. Commands are entered either by selecting options presented in a series of nested menus or by typing mnemonic Alt-key combinations.

The program can maintain up to four windows at a time, can import and export ASCII text, and has mail-merge capabilities. It supports margins up to 127 characters and can scroll horizontally. Other features include automatic hyphenation with a dictionary of more than 3000 cases, a 60-line buffer from which deleted text can be retrieved, access to DOS commands, word counting, and a spelling checker with a 70,000-word expandable dictionary.

DAC Easy Word requires at least 256K bytes of RAM and DOS 2.0 or higher. With 256K bytes of memory, the program can handle about 70 pages of text. It costs $49.95. Contact DAC Software Inc., 4801 Spring Valley Rd., Building 110-B, Dallas, TX 75244, (214) 458-60038.
Inquiry 558.

CAD Software for the IBM PC

Generic CADD from Generic Software is a $99.95 program for computer-aided design and drafting with the IBM PC. You can use it to design and draft in two dimensions on the computer screen using multiple layers, multiple line types, rubber-banding of lines and windows, user-definable video and digitizer menus, and component libraries. You draw with a mouse, digitizer, or keystroke commands.

The program features absolute or relative coordinate input, floating-point-based data, and unlimited picture size. The number of entities in a single drawing is limited only by memory size (640K bytes of RAM will allow approximately 40K lines).

You can choose from point, straight-line, rectangle, regular-polygon, circle, arc, ellipse, and curve (B-spline) drawing entities. You can select 256 layers, 256 colors, and 256 line types. The program provides for measurement of lengths, angles, and areas. Text placed in drawings can be scaled or rotated; multiple fonts are available.

Component libraries in Generic CADD can hold up to 256 different components for a single drawing. Such components can be included on menus and can be rotated, scaled, stretched, shrunk, or mirrored.

Generic CADD requires an IBM PC or compatible with at least 256K bytes of RAM, a video graphics board, an 8087 coprocessor (or an 80287 for an IBM AT), two floppy-disk drives, and DOS 2.0 or above. The recommended system configuration is a PC with 512K bytes or more of RAM, a medium-resolution video graphics board (720 by 350 monochrome or 640 by 400 color), a 10-megabyte hard-disk drive, a 12- by 12-inch digitizer, and a plotter. Generic CADD is priced at $99.95 with a 60-day unconditional money-back guarantee. Contact Generic Software Inc., 6 Lake Bellevue #203, Bellevue, WA 98005, (206) 462-1944.
Inquiry 559.

Macintosh Telecommunications

MicroPhone is a Macintosh telecommunications program written by Dennis Brothers, author of the public-domain program MacTEP. MicroPhone can emulate DEC VT-100, VT-52, and TTY-type terminals and provides ASCII and XMODEM file-transfer capabilities. Apple's Switcher is packaged with MicroPhone so that other applications

(continued)

NEW FROM BORLAND!

Borland introduces *Turbo* Lightning™ the fastest, most amazing information system since your brain

You can now find out everything in a flash. With instant access to electronic versions of the 83,000 word *Turbo* Lightning™ Random House® Speller & Word List; the 50,000-word *Turbo* Lightning Random House Thesaurus™ and the soon-to-be-released *Turbo* Lightning Encyclopedia™ — and to an astonishing array of electronic reference books which form Borland's new *Turbo* Lightning Library™.

Hitting one key on your IBM® personal computer — taps you into this new electronic age of instant information.

You get the right word, the right spelling, the right name, the right address, right now.

What we've done has been called "Artificial Intelligence," we simply call it "*Turbo* Lightning." This information revolution — driven by *Turbo* Lightning — means that the way you look things up is definitely looking up.

No matter what program you're running, *Turbo* Lightning instantly checks your spelling *as you type*. You could be running WordStar®, MultiMate™, SideKick®, Microsoft® Word, MCI Mail®, CompuServe®, or whatever, because as you work, as you write, *Turbo* Lightning is waiting in the wings, watching how you spell every word, but not getting in the way of what you're doing.

So how does it work? Let's say the word you meant to type was "RIGHT," but you accidentally typed 'RIHGT," which is wrong. What happens then?

You immediately *hear* a '*beep*,' so you know there was a boo-boo. You instantly *see* a window, that doesn't list "RIHGT" but it does list 'RIGHT' and its sound-alike words. So your screen looks like this:

```
rihgt
Sound Alike Words
A: right
B: rights
C: righted
D: rightly
E: relight
F: righter
G. Add word to auxiliary dictionary
PgUp or PgDn for more words
```

So you move your cursor to "A." which is the right "right," hit Return and the spelling mistake is instantly fixed. And the program you were working on has continued to run while you did a little spelling sidetrip with *Turbo* Lightning. *(If you'd rather not remember your Spelling grades in school, the beep might make you nuts, but you can choose the "whole page" option. Which means that when you finish writing the entire page, any spelling mistakes will be highlighted. You go in and straighten things out straight away).*

Lightning never goes away, is 100% concurrent, reliable, accurate and cannot, does not, will not 'crash & burn.'

Your document, letter, report, spreadsheet is word perfect and no one ever knows that you can't spell for *beens*.

***Turbo* Lightning does a lot more than spell "right" right, it also gives you instant synonyms.** Because you also have *Turbo* Lightning's Random House Thesaurus at your fingertips, you can really get to know your 'rights.' So back to the word "Right," but this time in the thesaurus. Type in "Right" and what you see in the on-screen window is:

```
right
Synonyms
-Adjective-
A: straight
B: true
C: accurate
D: sound
E: normal
-Noun-
F: claim
G: title
H: due
I: ownership
PgUp or PgDn for more words
```

So you instantly know more than one way to say, "The Boss is always right," which is handy if you get cornered and have to lie like that.

Introduce yourself to *Turbo* Lightning and it will never ever forget your name. It's conceivable, if unfair, that your name is not in the dictionary already, but you can instantly teach *Turbo* Lightning your name and all the other names and words it needs to know to help run your business or personal life.

Once you've taught *Turbo* Lightning what it needs to know, you'll never blow it with a letter to the *Joint Cheefs of Staff*, the *Raygan White Howse* or mess something up on your IMB PC. (IMB PC is not a trademark of International Business Machine Corp!)

Not $500, not $400, not $300, not $200, not $100, just $99.95 for this instant electronic miracle. Our success is pretty simple. We're not greedy. We believe that it is better to sell hundreds of thousands of software programs at a reasonable price—instead of a few at prices that would make Jesse James blush.

Just $99.95 gets you into the *Turbo* Lightning Library—which is an incredible deal when you look at what you're getting. You're getting the 'access system'—*Turbo* Lightning—which is the "engine" that powers the whole *Turbo* Lightning Library. You're getting the "engine" plus the 83,000-word *Turbo* Lightning Random House Speller and Word List; the 50,000-word *Turbo* Lightning Random House Thesaurus. And you're getting all that for an *incredible* $99.95!

If you ever *write* a word, *think* a word or *say* a word, you need *Turbo* Lightning. We give you a 60-day money-back guarantee and of course there's no copy protection. $99.95 isn't much to pay for a mistake-free life. Not to mention an education. No matter who you are or what you do, you need *Turbo* Lightning. That $99.95 will be the best $99.95 you ever spent on yourself or your company.

Do yourself, your assistants, your secretary, your boss, your readers, your audience and your career a favor, get *Turbo* Lightning today!



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Inquiry 42 for End-Users. Inquiry 43 for DEALERS ONLY.

can be coresident with the program.

With MicroPhone, the Macintosh can automatically log on to a remote system, send and receive mail, transfer files, and log off, all without human intervention. Simpler macros can be activated with a single keystroke. Macros can be created using MicroPhone's "Watch Me" mode—in which the program observes prompts and keystrokes—or by using the program's Script window menus, or a combination of the two.

MicroPhone has a list price of $74.95. For more information, contact Software Ventures Corp., 2907 Claremont Ave., Suite 220, Berkeley, CA 94705, (800) 336-6477; in California, (800) 336-6478; in Canada, (800) 336-6479.

Inquiry **560.**

Equity II and Equity III

Epson has released the Equity II, an IBM PC-compatible, and the Equity III, which is compatible with the PC AT.

The Equity II is based on NEC's 8086-compatible V30 microprocessor. While the Equity II normally operates at 7.16 MHz, it can also run timing-critical software at the same 4.77-MHz clock speed as the IBM PC. The Equity II includes a keyboard similar to the one shipped with IBM's PC AT, but without LEDs. For operator convenience, the power switch, volume control, and all DIP switches are located behind a drop-down front panel.

A combined monochrome/color-graphics controller, floppy-disk controller, serial and parallel ports, and 640K bytes of RAM are on the main system board. A 100-watt power supply, five open expansion slots, and space for up to two half-height disk drives allow for additional hardware. The system power can be turned on with the front-panel power switch or optionally by a preset timer or whenever the serial port detects a ring-detect signal. Power can be turned off manually or through a software command.



Epson's Equity II (right) and Equity III.

Like the PC AT, the Equity III includes eight expansion slots, a single 1.2-megabyte disk drive, serial and parallel ports, and room for up to four internal half-height disk drives. A hard-disk controller and 640K-byte RAM are also standard.

The Equity II with one 360K-byte disk drive will retail for under $1900. The Equity III with one 1.2-megabyte drive will be priced under $3500. Contact Epson America, Computer Products Division, 2780 Lomita Blvd., Torrance, CA 90505, (213) 539-9140.

Inquiry **561.**

Data-Compression Units Multiply Modem Speed

Adaptive Computer Technologies now offers the ACT-1200A and the ACT-2400A, data-compression units for use with 1200- and 2400-bps full-duplex modems. These devices are stand-alone boxes that interface not only to modems but to terminals and computers through an RS-232C cable. They can be used for modem file transfer, transmission to a printer, or general, interactive terminal-to-computer work. To compress data, you need to have an ACT unit at each end of the line. However, the units do have a transparent mode that does not compress data but simply passes it along.

The ACT compression units analyze transmitted data and use statistical characteristics about that data to select a compression scheme. The units can stay with built-in tables, or they can invoke a dynamic history feature and agree to work with a new table based on the last few thousand characters. Because the units will derive the same new table, one doesn't have to send the entire table to the other; a short message suffices.

Repetitive strings are compressed using variable bit-length encoding. The compression ratio is not directly related to the type of file: Database files and text files will see the same sorts of compression. Compression factors range as high as 5:1, but 2:1 or 3:1 is typical. Encoding and decoding also incorporate a full CRC-16 error-correction process.

A series of menus lets you set certain compatibility and transmission options, which are then stored in nonvolatile memory inside the unit. You can modify the handshaking that alerts the units to the presence or absence of another compressor at the other end of the line.

The ACT-1200A costs $595. The ACT-2400A costs $795. Contact Adaptive Computer Technologies, 97 Boston Ave., Suite 103, San Jose, CA 95128, (408) 279-3993.

Inquiry **562.**

Synthesizer Attaches to Parallel Port

Rayna Systems has developed a high-performance music synthesizer that can attach to almost any computer through a parallel printer port. The synthesizer has 59 oscillators, all of which have programmable frequency, volume, and waveform.

These oscillators can be combined to produce a varied collection of sounds. In addition, output can be channeled into any of four output jacks to provide quadraphonic sound. A sample BASIC program shows how the synthesizer can be set up. For CP/M systems, additional software is available, including a $150 program that allows you to edit musical note sequences and instrument characteristics in real time.

The price of the Rayna Synth-in-a-Box is $850. As an S-100 board, the product costs $650. Contact Rayna Systems, 460 9th St., Brooklyn, NY 11215, (718) 499-8457.

Inquiry **563.**

(continued on page 408)

A·S·K B·Y·T·E

Conducted by Steve Ciarcia

RAM FOR APPLE

Dear Steve,

I have a 294K-byte RAM card made by "Syntex, Redmond" for the Apple II. Apparently, the company was originally located in the state of Washington and merged with another company.

I need information on installation and use of the product. Any help you could give me would be appreciated.

STAN REED
Eagle River, AK

There was a company called Syntex in Redmond, Washington, that made a RAM card for the Apple called Flashcard. That company, however, is no longer in business. An Apple Pascal 1.2 driver to configure the Flashcard as a soft disk drive is available from

A.P.P.L.E. Co-op
290 Southwest 43rd St.
Renton, WA 98055

ProDOS drivers are available from

Microseeds
20 Goodell Rd.
Stafford Springs, CT 06076

—Steve

6502 MATH

Dear Steve,

Do you know of a book that explains 6502 math utilities? I need something that develops the algorithms for floating point, random numbers, rounding errors, trigonometric functions, logarithms, powers, roots, and so on.

I'm in prison here in Texas, and I work in the electronics shop. I use an Apple IIe and would like to write my own math functions, but I've been hampered by the lack of proper algorithms. I managed to figure out a floating-point format using a 64-bit mantissa, a 15-bit characteristic, and a sign bit. After that, the only algorithm I could find was a Taylor power series in a calculator book.

It is very frustrating to order computer books by mail without any recommendations. I don't have any reference library except the one I have put together myself.

MICHAEL SANDERS
Huntsville, TX

Three good sources of the kind of information you are seeking are

Ahl, David H. Computers in Mathematics: A Sourcebook of Ideas *(Creative Computing Press)*

Bennett, William. Scientific and Engineering Problem-Solving with the Computer *(Prentice-Hall)*

Knuth, Donald E. The Art of Computer Programming, Volume 2: Semi-Numerical Algorithms *(Addison-Wesley)*

Current prices and relevant ordering information can be obtained by writing directly to the publishers.—Steve

JUST ONE MINOR QUESTION

Dear Steve,

Could you advise me on how to learn more about microcomputers? I do have some computer background: I've taken graduate physics courses in micros and courses in FORTRAN, assembly language, and the use of BASIC and machine language. I've also used RCA and DEC mainframe computers.

I am looking for a way to make an Atari run Commodore and Apple programs, since they all use the 6502 processor. Can you use tristate buffers to switch to different operating-system ROMs, I/O ports, etc.? This leads me to ask about emulation—is it an advanced program lookup table (what *is* a lookup table?) that makes the processor think it is in a different machine? Or does it just translate the program to the other machine's requirements? Can an emulation ROM be bank-switched in to translate the program?

I've read that an operating system has been written in the C programming language. How? I've looked at a couple of operating-system programs, but I admit I don't know much about the subject. I couldn't write my own, and I have only a vague concept of the BIOS. How can I learn lots more?

How does the Commodore C-128 tie together the 6502 and the Z80? Using a coprocessor? (What is a coprocessor?) How does the Heath/Zenith H-89 use one Z80 to control a second Z80 in a processor/slave arrangement? Where can I learn how to use a Z80 or a 6502 to control a 68000? How does the operating system control parallel processors, such as an 8086 with an 8087?

I'm not sure I understand the DMA concept or how a cache memory works. How are programs (and the operating system) written to handle a RAM disk? A bubble memory? Can dynamic memory be used in the RAM disk? How is refreshing handled?

MSX is being promoted as an 8-bit operating-system standard. Where can I find out more? Can I convert an old Radio Shack computer to use MSX? How? Where can I find an operating-system ROM?

I think I know some basics about micros, but where do I go for an intermediate education? I do try to read BYTE regularly—especially your articles—but sometimes I have more questions than understanding.

MERLE RUMMEL
Liberty, IN

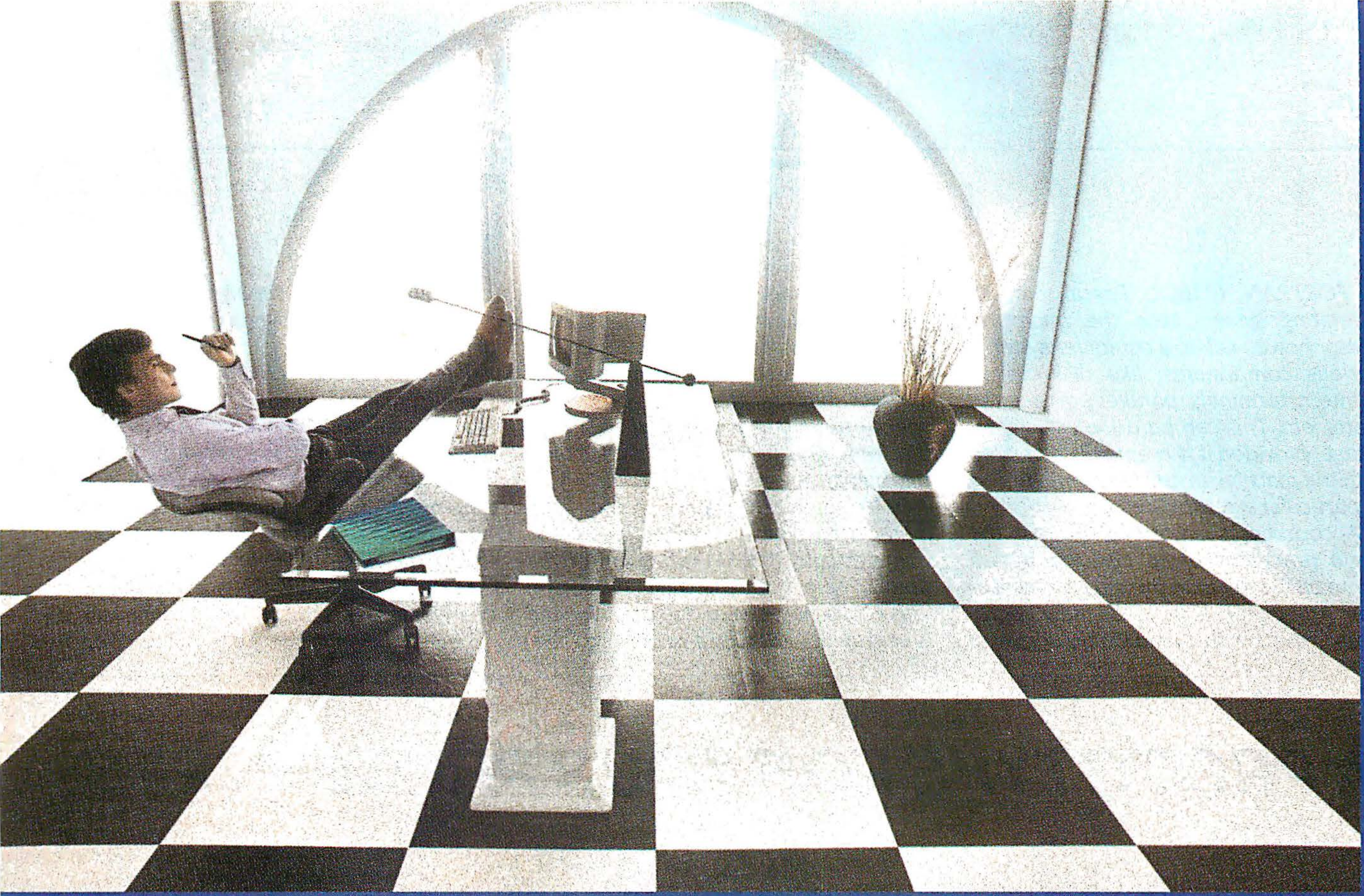
Mr. Rummel, you ask a lotta questions.

Your letter is filled with questions ranging from basics to advanced hardware/software techniques. As a beginning, the best way to learn a subject is to read and experiment. You should have some computer-related textbooks left over from college that would provide a good start. In addition, a trip to your library and a well-stocked bookstore will provide a wealth of computer-related information. You can select books that furnish information at a level you can understand.

Making a series of computers that utilize the same microprocessor chip (and therefore the same instruction set) is not as simple as changing an operating-system ROM. The address locations of the I/O ports on one machine are usually different from those on another. This means that you have to change one machine's operating system's port addresses to fit the new machine. Device addresses, memory addresses, etc., are set by hardware, not software. Consequently, a program that runs on an Apple will not load and run successfully on a Commodore or Atari computer, even though they all share the same microprocessor.

An operating system can be written in

(continued)



C, FORTRAN, COBOL, Pascal, etc. An operating system tells the microprocessor how to talk to a computer system's various components, like disk drives, printers, terminals, parallel ports, serial ports, etc. This can be done in any language, provided it is eventually compiled into the machine instructions required by a particular microprocessor.

A coprocessor is used to assist the main processor or to perform a task more efficiently than the main processor can. An example is the 8087 math coprocessor used with the 8088/86 series of microprocessors. The 8087 performs mathematical computations many times faster than the 8088/86. Since a coprocessor usually shares the same data and address bus as the main processor, special hardware is required to assure that only one processor has control of the bus at any given time.

DMA (direct memory access) is a method by which a device reads and writes directly to RAM without intervention or help from the main processor. This allows high-speed data transfer and is usually provided by a dedicated DMA controller chip or a separate processor.

A RAM disk is a program that sets aside a portion of memory for use as a disk drive. It does this by fooling the operating system into "thinking" that this RAM is a physical drive. Dynamic RAM can be used as a RAM disk, as can bubble memory and static RAM. The operating system and RAM-disk program don't care if the memory is dynamic, bubble, or static; these are all handled by hardware.

Since dynamic memory is based on charge-storage in capacitors, rather than

(continued)

The C for Microcomputers

AZTEC C

PC-DOS, MS-DOS, CP/M-86, Macintosh, Amiga, Apple II, CP/M-80, Radio Shack, Commodore, XENIX, ROM, and Cross Development systems

MS-DOS, PC-DOS, CP/M-86, XENIX, 8086/80x86 ROM

Manx Aztec C86

"A compiler that has many strengths . . . quite valuable for serious work"

Computer Language review, February 1985

Great Code: Manx Aztec C86 generates fast executing compact code. The benchmark results below are from a study conducted by Manx. The Dhrystone benchmark (CACM 10/84 27:10 p1018) measures performance for a systems software instruction mix. The results are without register variables. With register variables, Manx, Microsoft, and Mark Williams run proportionately faster, Lattice and Computer Innovations show no improvement.

	Execution Time	Code Size	Compile/ Link Time
Dhrystone Benchmark			
Manx Aztec C86 3.3	34 secs	5,760	93 secs
Microsoft C 3.0	34 secs	7,146	119 secs
Optimized C86 2.20J	53 secs	11,009	172 secs
Mark Williams 2.0	56 secs	12,980	113 secs
Lattice 2.14	89 secs	20,404	117 secs

Great Features: Manx Aztec C86 is bundled with a powerful array of well documented productivity tools, library routines and features.

Optimized C compiler	Symbolic Debugger
AS86 Macro Assembler	LN86 Overlay Linker
80186/80286 Support	Librarian
8087/80287 Sensing Lib	Profiler
Extensive UNIX Library	DOS, Screen, & Graphics Lib
Large Memory Model	Intel Object Option
Z (vi) Source Editor -c	CP/M-86 Library -c
ROM Support Package -c	INTEL HEX Utility -c
Library Source Code -c	Mixed memory models -c
MAKE, DIFF, and GREP -c	Source Debugger -c
One year of updates -c	CP/M-86 Library -c

Manx offers two commercial development systems, Aztec C86-c and Aztec C86-d. Items marked -c are special features of the Aztec C86-c system.

Aztec C86-c Commercial System	**$499**
Aztec C86-d Developer's System	**$299**
Aztec C86-p Personal System	**$199**
Aztec C86-a Apprentice System	**$49**

All systems are upgradable by paying the difference in price plus $10.

Third Party Software: There are a number of high quality support packages for Manx Aztec C86 for screen management, graphics, database management, and software development.

C-tree $395	**Greenleaf $185**
PHACT $250	**PC-lint $98**
HALO $250	**Amber Windows $59**
PRE-C $395	**Windows for C $195**
WindScreen $149	**FirsTime $295**
SunScreen $99	**C Util Lib $185**
PANEL $295	**Plink-86 $395**

MACINTOSH, AMIGA, XENIX, CP/M-68K, 68k ROM

Manx Aztec C68k

"Library handling is very flexible . . . documentation is excellent . . . the shell a pleasure to work in . . . blows away the competition for pure compile speed . . . an excellent effort."

Computer Language review, April 1985

Aztec C68k is the most widely used commercial C compiler for the Macintosh. Its quality, performance, and completeness place Manx Aztec C68k in a position beyond comparison. It is available in several upgradable versions.

Optimized C	Creates Clickable Applications
Macro Assembler	Mouse Enhanced SHELL
Overlay Linker	Easy Access to Mac Toolbox
Resource Compiler	UNIX Library Functions
Debuggers	Terminal Emulator (Source)
Librarian	Clear Detailed Documentation
Source Editor	C-Stuff Library
MacRam Disk -c	UniTools (vi,make,diff,grep) -c
Library Source -c	One Year of Updates -c

Items marked -c are available only in the Manx Aztec C86-c system. Other features are in both the Aztec C86-d and Aztec C86-c systems.

Aztec C68k-c Commercial System	**$499**
Aztec C68d-d Developer's System	**$299**
Aztec C68k-p Personal System	**$199**
C-tree database (source)	**$399**
AMIGA, CP/M-68k, 68k UNIX	**call**

Apple II, Commodore, 65xx, 65C02 ROM

Manx Aztec C65

"The AZTEC C system is one of the finest software packages I have seen"

NIBBLE review, July 1984

A vast amount of business, consumer, and educational software is implemented in Manx Aztec C65. The quality and comprehensiveness of this system is competitive with 16 bit C systems. The system includes a full optimized C compiler, 6502 assembler, linkage editor, UNIX library, screen and graphics libraries, shell, and much more. The Apple II version runs under DOS 3.3, and ProDOS, Cross versions are available.

The Aztec C65-c/128 Commodore system runs under the C128 CP/M environment and generates programs for the C64, C128, and CP/M environments. Call for prices and availability of Apprentice, Personal and Developer versions for the Commodore 64 and 128 machines.

Aztec C65-c ProDOS & DOS 3.3	**$399**
Aztec C65-d Apple DOS 3.3	**$199**
Aztec C65-p Apple Personal system	**$99**
Aztec C65-a for learning C	**$49**
Aztec C65-c/128 C64, C128, CP/M	**$399**

Distribution of Manx Aztec C

In the USA, Manx Software Systems is the sole and exclusive distributor of Aztec C. Any telephone or mail order sales other than through Manx are unauthorized.

Manx Cross Development Systems

Cross developed programs are edited, compiled, assembled, and linked on one machine (the HOST) and transferred to another machine (the TARGET) for execution. This method is useful where the target machine is slower or more limited than the HOST. Manx cross compilers are used heavily to develop software for business, consumer, scientific, industrial, research, and educational applications.

HOSTS: VAX UNIX ($3000), PDP-11 UNIX ($2000), MS-DOS ($750), CP/M ($750), MACINTOSH ($750), CP/M-68k ($750), XENIX ($750).

TARGETS: MS-DOS, CP/M-86, Macintosh, CP/M-68k, CP/M-80, TRS-80 3 & 4, Apple II, Commodore C64, 8086/80x86 ROM, 68xxx ROM, 8080/8085/Z80 ROM, 65xx ROM.

The first TARGET is included in the price of the HOST system. Additional TARGETS are $300 to $500 (non VAX) or $1000 (VAX).

Call Manx for information on cross development to the 68000, 65816, Amiga, C128, CP/M-68K, VRTX, and others.

CP/M, Radio Shack, 8080/8085/Z80 ROM

Manx Aztec CII

"I've had a lot of experience with different C compilers, but the Aztec C80 Compiler and Professional Development System is the best I've seen."

80-Micro, December, 1984, John B. Harrell III

Aztec C II-c (CP/M & ROM)	**$349**
Aztec C II-d (CP/M)	**$199**
C-tree database (source)	**$399**
Aztec C80-c (TRS-80 3 & 4)	**$299**
Aztec C80-d (TRS-80 3 & 4)	**$199**

How To Become an Aztec C User

To become an Aztec C user call 1-800-221-0440 or call 1-800-832-9273 (800-TEC WARE). In NJ or outside the USA call 201-530-7997. Orders can also be telexed to 4995812.

Payment can be by check, COD, American Express, VISA, Master Card, or Net 30 to qualified customers.

Orders can also be mailed to Manx Software Systems, Box 55, Shrewsbury, NJ 07701.

How To Get More Information

To get more information on Manx Aztec C and related products, call 1-800-221-0440, or 201-530-7997, or write to Manx Software Systems.

30 Day Guarantee

Any Manx Aztec C development system can be returned within 30 days for a refund if it fails to meet your needs. The only restrictions are that the original purchase must be directly from Manx, shipped within the USA, and the package must be in resalable condition. Returned items must be received by Manx within 30 days. A small restocking fee may be required.

Discounts

There are special discounts available to professors, students, and consultants. A discount is also available on a "trade in" basis for users of competing systems. Call for information.

Inquiry 222

MANX

To order or for information call:

800-221-0440

UNIX is a registered TM of Bell Laboratories, Lattice TM Lattice Inc., C-tree TM Faircom, Inc., PHACT TM PHACT ASSOC., CI Optimizing C86 TM Computer Innovations, Inc., MACINTOSH, APPLE TM APPLE, INC., Pre-C, PLINK 86, TM PHOENIX, HALO TM Media Cybernetics, Inc., C-terp, PC-lint TM GIMPLE Software, Windscreen, SunScreen TM SunTec, PANEL TM Roundhill Computer Systems Ltd., WINDOWS FOR C TM Creative Solutions, XENIX, MS TM MICROSOFT INC., CP/M TM DRI, AMIGA, C64, C128 TM COMMODORE Int.

a flip-flop circuit (as in static memory), dynamic RAM requires a periodic refresh pulse to offset the effects of the capacitor's leakage. This refresh pulse is provided either by the processor (such as the Z80's refresh pin) or some other timed-pulse generating circuitry.

As far as converting a Radio Shack computer to run an operating system other than what it was designed for, I suggest you visit your local Radio Shack computer store and discuss the details of this with them.—Steve

VERSACARD

Dear Steve,

I have a problem with my Prometheus VERSAcard in my Apple II. I've sent several letters to the manufacturer with no reply.

When I use my Signalman Mark XII modem at 1200 bps, the VERSAcard drops between five and eight characters following each carriage return. This occurs in either a 40- or 80-column display. I've tried four terminal programs with the same result. I've also tried the modem on two other computers with no problem. Do you have any ideas?

STEVE NELSON
Euless, TX

This type of problem is frequently due to incompatible or inadequate handshaking signals: The VERSAcard and the modem may not know who's going to do what, and when. I would suspect the DTR (data terminal ready) signal, pin 20, on the standard DB-25 connector. On the VERSAcard, this line is tied permanently high. The Signalman modem, in its default configuration, uses this line to determine when the VERSAcard is ready for more data.

As characters are received through the modem and serial card, the terminal program stores them in a buffer (frequently, the Apple's keyboard-input buffer is used for this purpose). When a carriage-return character is received, the terminal program signals the modem to stop sending data and processes this buffer. If the modem doesn't receive this signal, it will continue sending characters and the terminal program will miss some characters.

If the DTR signal is the cause of your problem, the solution is probably attained most easily in software. You should configure your modem to ignore the DTR line, then implement a suitable software handshaking protocol, like the XON/XOFF protocol. The terminal program you are using will determine which software protocols you can use. Two terminal programs that work well with the VERSAcard/Signalman combination are ASCII Express, from United Software, and Modem Magician, available from A.P.P.L.E. Co-op, 290 Southwest 43rd St., Renton, WA 98055.—Steve

MUSIC, MUSIC, MUSIC

Dear Steve,

Some friends and I are developing software for producing printed output in musical notation from data input by a musical keyboard. At the moment, we are using a Wersi organ because it delivers logical MIDI (musical instrument digital interface) data in physical RS-232C format. This organ is very expensive, and we would like to use a much cheaper MIDI keyboard. Since the computer we are using has only an RS-232C serial interface, we will need a MIDI-to-RS-232C converter. Do you know of any such converter?

ERICH NEUWIRTH
Vienna, Austria

Ferro Productions (228 Washington Ave., Belleville, NJ 07109, (201) 751-6238) has written several tutorials on the MIDI and music synthesis. According to a company source, they will be releasing a new MIDI course in the next few months. In addition, a book will be available that also covers this subject. Contact the company for information concerning the course.

The book, MIDI and Related Interfaces, *will be available through*

Cherry Lane Music
POB 430
Port Chester, NY 10573
(914) 937-8601

You should also check into MIDI boards that plug directly into most personal computers. Cherry Lane Music carries such hardware, as does

Syntech Corporation
23958 Craftsman Rd.
Calabasas, CA 91302
(818) 704-8509

—Steve

HARDWARE EDUCATION

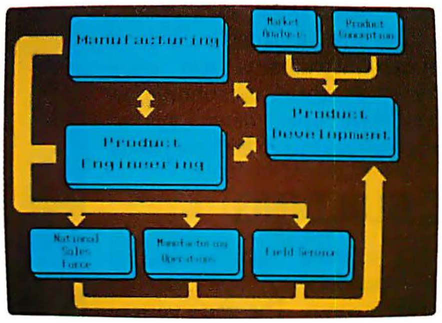
Dear Steve,

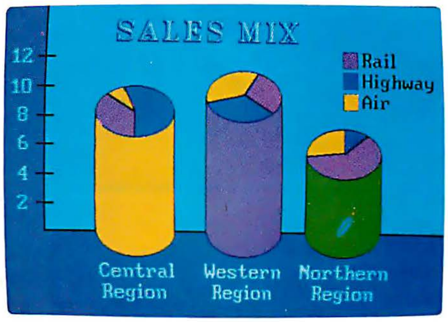
I have been in the computer field for about six years and have done mostly software work. My only hardware project was building an S-100 system for my own use.

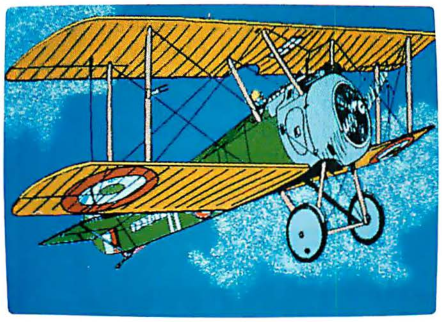
(continued)

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The pen is mightier than the keyboard.

None of history's great artists drew with a keyboard, and you shouldn't have to either. So PC Paintbrush is now available with a cordless PenMouse, to give you complete freedom of expression. Of course, it also supports regular mice, joysticks, graphics tablets, and is compatible with most graphics cards.

PC Paintbrush also has a beautiful way with words. The text icon lets you write in any of eleven fonts, in nine sizes, with italics, outline, shadow and boldface variations.

What's more, with the new 3.0 PC Paintbrush, you can draw rounded boxes, rubber band curves and circles, and edit pictures many times larger than the screen.

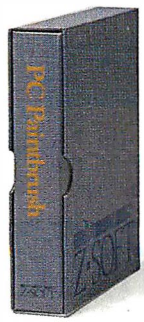
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Inquiry 401 for End-Users. Inquiry 402 for DEALERS ONLY.

I am writing for some advice on how I can learn about hardware, enough so that I will be able to troubleshoot and repair microprocessor systems.

If you could recommend some books or courses, I would greatly appreciate it.

LEONARD SIMON
Kenvil, NJ

A good way to learn a subject is to familiarize yourself with the selection of books at your local library on the topic of interest. This is also an inexpensive approach since you don't have to purchase books that are either too technical or too basic for you. In addition, authors and publishers of a book that is useful for a particular subject generally publish related works, a handy source for contacts. You can also stop by a well-stocked bookstore and browse through its selection of electronics and computer-related publications. I have found many interesting books this way.

Howard W. Sams publishes a set of five books called Basic Electricity and Electronics. *Each book sells for $10.95. A few more useful books from Sams are* Digital Logic Circuits: Tests and Analysis *by Robert G. Middleton ($16.95) and* Microprocessor Circuits *by Edward M. Noll ($9.95 for each of two volumes). All these books can be obtained from the publisher or from the following company:*

Hughes-Peters Inc.
481 East Eleventh Ave.
Columbus, OH 43211
(614) 294-5351

The use of home-study courses and technical schools provides for the best training. You are offered assistance when required and receive feedback as to your progress and knowledge in the form of grades.—Steve ■

IN ASK BYTE, *Steve Ciarcia answers questions on any area of microcomputing. The most representative questions received each month will be answered and published. Do you have a nagging problem? Send your inquiry to*

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Glastonbury, CT 06033

Due to the high volume of inquiries, personal replies cannot be given. All letters and photographs become the property of Steve Ciarcia and cannot be returned. Be sure to include "Ask BYTE" in the address.

The Ask BYTE staff includes manager Harv Weiner and researchers Larry Bregoli, Bill Curlew, Jeannette Dojan, Jon Elson, Roger James, Frank Kuechmann, Dick Sawyer, Andy Siska, and Robert Stek.

MICROSOFT LANGUAGES NEWSLETTER Vol. 1-1

News about the Microsoft Language Family

Faster Macro Assembler 4.00 release developed in Microsoft C

By porting the new Macro Assembler 4.00 release to Microsoft C, it assembles programs from 2 to 3 times faster than the previous Microsoft 3.00 and IBM® 2.00 releases. The mixed language and memory model support unique to Microsoft C allowed the new assembler to be written as a small model program using the more efficient Pascal calling conversions for all internal functions. Macro text, symbol names and file buffers were moved out of the 64K "near" workspace into "far" memory allowing much larger programs to be assembled. Additional performance tuning was possible in C by using register variables throughout the assembler. Final profiling identified a few critical small routines to write in assembly language.

The source symbolic debugger, SYMDEB, has been enhanced to include screen swapping, stack backtracing, DOS command execution, better source display and debugging features making this the ideal tool for debugging programs. The 25% faster LINK and the EXEPACK utility can compress executable files by removing common sequences and optimizing the relocation tables. The MAKE utility now supports macros and inference rules.

We are committed to making the complete Macro Assembler product the best value in PC development tools.

News for Microsoft and IBM COBOL users

The new Microsoft® COBOL 2.1 release for MS-DOS® and XENIX® features faster execution and support for the new COBOL Tools package which contains VIEWCOB, COBREF, Menu Handler, and CBMOUSE (MS-DOS only). VIEWCOB is an interactive symbolic debugger with an easy-to-learn, menu-driven user interface which supports on-line help and up to 10 windows on your source text, variables, memory, and procedure traces. The COBOL trace mode highlights each statement as it is executed. COBREF is an advanced COBOL cross reference generator that displays lists of files, variables with types, and procedures. Menu Handler and CBMOUSE allow the COBOL programmer to create menu-driven applications to interface to the Microsoft Mouse.

Microsoft C Selected for the IBM personal computer C compiler

The IBM C compiler is a repackaging of the Microsoft C Compiler with a few utilities from the Microsoft Macro Assembler product. A XENIX version of the same compiler is part of Microsoft's XENIX system V release. IBM also distributes Microsoft BASIC, COBOL, FORTRAN, and Pascal compilers, BASIC interpreter and Macro Assembler under its own logo. Microsoft offers special upgrade pricing to owners of certain Microsoft languages purchased through IBM. Call us for more information.

Write to: MICROSOFT Languages Newsletter
10700 Northup Way, Box 97200
Bellevue, WA 98009 for product update and information.
Or phone:
(800) 426-9400. In Washington State and Alaska,
(206) 828-8088. In Canada, call (416) 673-7638.

Latest DOS Versions:

C	3.00
COBOL	2.10
FORTRAN	3.31
Macro Assembler	4.00
Pascal	3.31
QuickBASIC	1.00

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ASSIMILATION, Numeric Turbo	$ 149	$ 109
Mac Port Adaptor	$ 79	$ 59
BLUECHIP, Millionaire, Barron, Tycoon, ea.	$ 60	$ 38
BORLAND, Sidekick (copiable)	$ 85	$ 45
CENTRAL POINT, Copy II Mac	$ 40	$ 22
CONROY-LA POINTE, Diskettes	SEE BELOW	
CONTINENTAL, Home Accountant	$ 100	$ 65
CREIGHTON, Home Pak or Mac Office, ea.	$ 39	$ 33
Mac Spell+	$ 99	$ 61
DOW JONES, Market Manager Plus	$ 249	$ 159
EXPERTELLIGENCE, ExperLogo	$ 150	$ 95
FIRST BYTE, Smooth Talker	$ 100	$ 63
FORETHOUGHT, Fact Finder	$ 150	$ 95
HABA, 400K Ext. Disk Drive	$ 449	$ 339
800K DS/DD Ext. Drive	$ 599	$ 489
HAYDEN, Sargon III	$ 50	$ 31
HUMAN EDGE, Mind Prober	$ 50	$ 29
INFOCOM, Hitchhiker's Guide	$ 40	$ 25
KOALA, Mac Vision	$ 400	$ 229
LIVING VIDEOTEXT, Think Tank	$ 145	$ 92
LOTUS, Jazz	$ 595	$ 389
MANHATTAN, ReadySetGo	$ 125	$ 69
MEGAHAUS, Megaform	$ 295	$ 189
MICROSOFT, Business Pak	$ 595	$ 399
Excel	$ 395	$ 248
Multiplan, Word, or File, each	$ 195	$ 129
Fortran	$ 295	$ 199
MILES, Mac the Knife, v. 1	$ 39	$ 25
MONOGRAM, Dollars & $ense	$ 150	$ 89
NOVATION, Smartcat Plus Modem w/Software	$ 499	$ 349
ODESTA, Helix	$ 395	$ 249
PROVUE, Overvue	$ 295	$ 195
SIMON & SCHUSTER, Typing Tutor III	$ 60	$ 39
SOFTW. PUBL., PFS: File & Report Combo	$ 175	$ 105
STATE OF THE ART, Electronic Checkbook	$ 80	$ 50
STONEWARE, DB Master	$ 195	$ 125
TELOS, File Vision	$ 195	$ 119
VIDEX, MacCalendar	$ 89	$ 49
WARNER, Desk Organizer	$ 149	$ 99

COMPUTERS

apple

IIe, IIc, Mac — IN STOCK, CALL

FLOPPY DISK DRIVES

	LIST	CONROY
MICRO-SCI, A2 Disk Drive, 143K	$ 269	$ 159
A2 Controller Card	$ 100	$ 59
Half Height Drive for II+/IIe	$ 269	$ 159
Half Height Drive for IIc	$ 299	$ 169
TEAC, T40 Half Ht, 163K, Direct	$ 249	$ 149
Controller Card for T40 by ComX	$ 79	$ 45

HARD DISKS

IOMEGA, 5 meg Bernoulli Box f/Mac	$1995	$1595
QUARK, QC10 for IIc/IIe/III/MAC	$1995	$1175

OTHER HARDWARE

APPLE, Mouse for IIe	$ 150	CALL
CCS, 7711 or 7710-A Interface, ea.	$ 115	$ 95
CPS/EASTSIDE, Wild Card II (copier, +/e)	$ 140	$ 79
COMX, 16K RAM Card (II+), 1 yr ltd wty	$ 119	$ 39
HAYES, Mach II, III Joysticks (II+/IIe)		CALL
KENSINGTON, System Saver Fan	$ 90	$ 65
KEY TRONIC, KB200 Keyboard (+)	$ 398	$ 248
KOALA, Muppet Keys	$ 80	$ 44
Touch Tablet w/Micro Illustrator (+/e)	$ 130	$ 75
KRAFT, Joystick (IIe/IIc)	$ 50	$ 25
MICRO-SCI, 80 Col. Card + 64K RAM Card (IIe)	$ 179	$ 89
MICROSOFT, Z80 Softcard II, 64K	$ 425	$ 269
ORANGE MICRO, Buffered Grappler Plus, 16K	$ 209	$ 145
16K Buffer Board for Grappler Plus	$ 99	$ 59
Hot Link, S-P cable for IIc	$ 70	$ 44
TITAN, Accelerator IIe	$ 319	$ 229
128K RAM Card (II+)	$ 329	$ 149
TRACKHOUSE, Numeric Key Pad (IIe)	$ 100	$ 87
VIDEO 7, V Color 7 RGB Card	$ 150	$ 129
V Color IIc	$ 130	$ 89
V Color IIe	$ 250	$ 169
VIDEX, UltraTerm 132 Col. (II+/IIe)	$ 299	$ 189
VideoTerm 80 Col. Card (II+/IIe)	$ 279	$ 175
WICO, Smartcard (spec. II/II+/IIe)	$ 199	$ 159

BUSINESS SOFTWARE

	LIST PRICE	CONROY PRICE
ALS, Word or List Handler, ea.	$ 80	$ 36
Handler Pak (Word/List/Spell)	$ 170	$ 73
APPLE, Appleworks	$ 250	$ 225
ASHTON-TATE, dBase II (Req CP/M 80)	$ 495	$ 289
BPI, AR, AP, PR or INV, each	$ 395	$ 240
DATA TRANS, Fontrix	$ 95	$ 63
DOW JONES, Market Analyzer	$ 349	$ 219
HOWARD SOFT, '86 Tax Preparer	$ 295	$ 199
HUMAN EDGE, Sales or Mgmt Edge, ea.	$ 250	$ 139
LIVING VIDEOTEXT, Think Tank	$ 145	$ 89
MEGAHAUS, Megaworks	$ 125	$ 79
MICRO PRO, WordStar (req. CP/M)	$ 350	$ 189
WordStar w/ Starcard	$ 495	$ 265
WordStar Professional, 4 Pak	$ 495	$ 265
MICROSOFT, Multi-Plan (Ap DOS)	$ 95	$ 65
QUARK, Word Juggler & Lexicheck (IIe/IIc)	$ 99	$ 79
SATELLITE, Word Perfect	$ 179	$ 115
SENSIBLE, Sensible Speller	$ 125	$ 79
SIERRA/ON-LINE, Screen Writer II	$ 130	$ 89
SOFTWARE PUBL, PFS:File or Write, each	$ 125	$ 79
PFS:Graph or Report, each	$ 125	$ 79
PFS:Access	$ 70	$ 43
First Success (F/R/W)	$ 225	$ 145
SPRINGBOARD, Newsroom	$ 50	$ 32
STONEWARE, DB Master, v. 4+	$ 350	$ 189

UTILITIES SOFTWARE

BEAGLE, GPLE or Alpha Plot, ea	$ 50	$ 27
Pronto DOS or Disk Quick, ea	$ 30	$ 19
Apple Mechanic or I.O. Silver	$ 30	$ 19
BORLAND, Turbo Pascal (req. CP/M)	$ 70	$ 36
Turbo Toolbox	$ 55	$ 30
CENTRAL POINT Copy II Plus (bit copier)	$ 40	$ 22
EPSON, Graphics Dump	$ 15	$ 7
FUNK, Sideways	$ 60	$ 37
HAYES, Terminal Prog. for Smartmodem	$ 99	$ 65
MICROSOFT, Full Line IN STOCK		CALL
MICROSTUF, Crosstalk	$ 195	$ 109
OMEGA, Locksmith	$ 100	$ 73
PENGUIN, Complete Graphics System II	$ 80	$ 49

UTILITIES SOFTWARE

	LIST PRICE	CONROY PRICE
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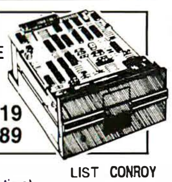
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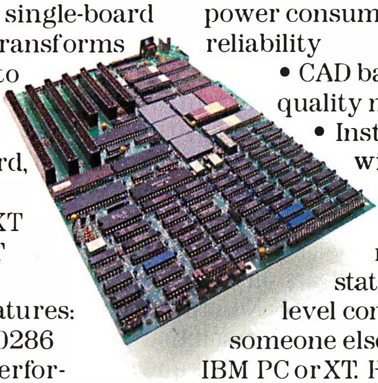
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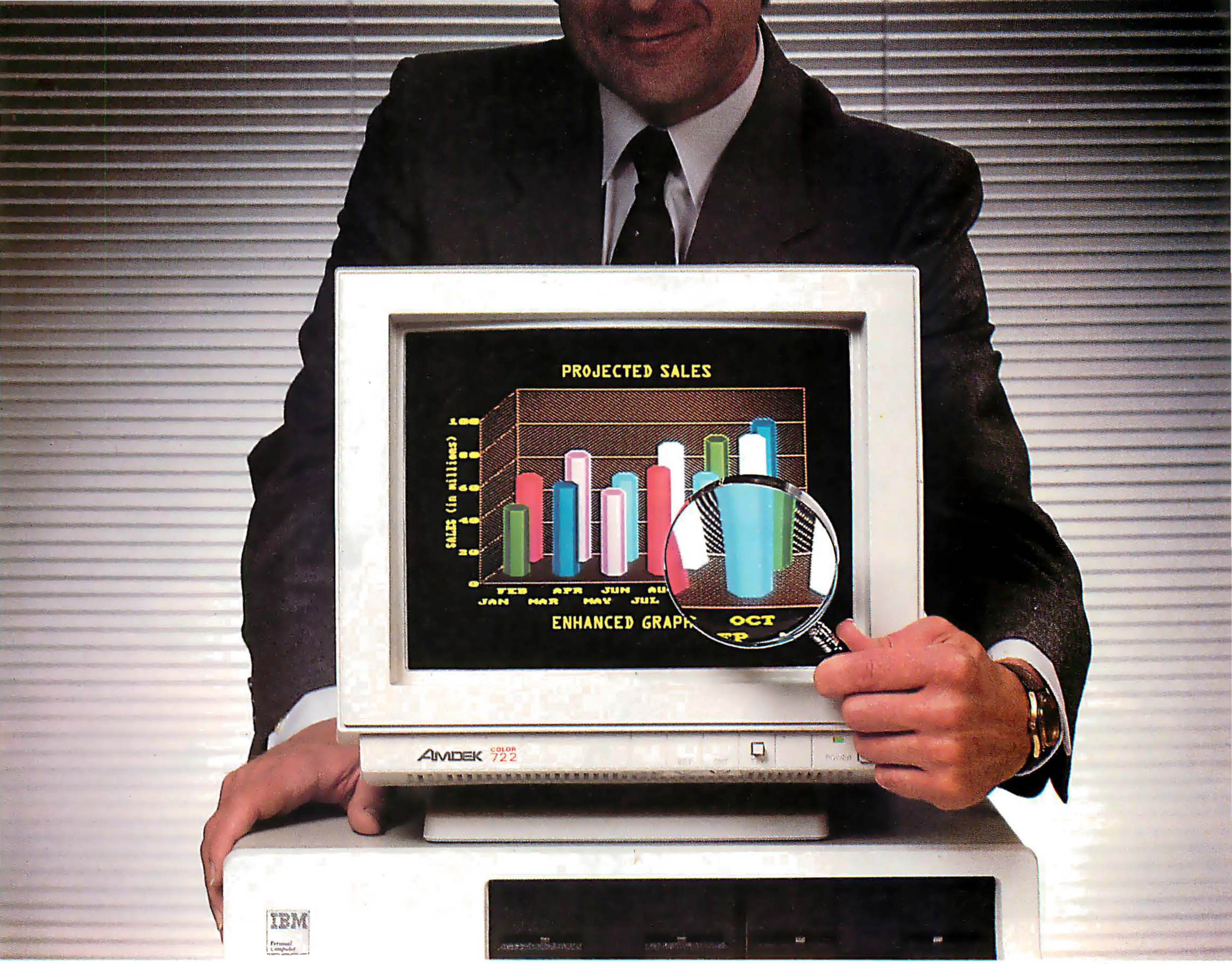
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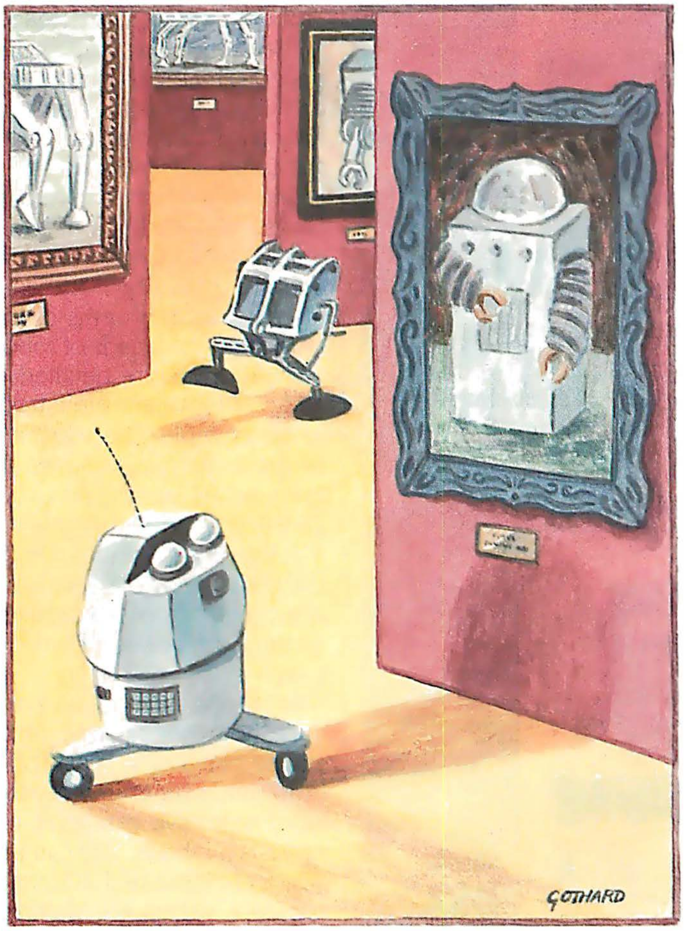
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TO ROBOTICS
Arthur J. Critchlow
Macmillan Publishing Co.
New York: 1985
528 pages, $35

THE MICROCOMPUTER
IN CELL AND
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R. Ranney Mize, editor
Elsevier Science
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Menlo Park, CA: 1985
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INTRODUCTION TO ROBOTICS

Reviewed by Larry Clark

The history behind the development of robots, their operational characteristics, and the benefits of their use are the focus of *Introduction to Robotics*. Arthur J. Critchlow prepared the chapters so that the first portion of each can be read casually; there's not an extreme amount of technical detail. An introductory course could even be gleaned from these parts of the book. He then closes the chapters with valuable technical matter for advanced readers. Although some repetition is evident, the dual level of presentation would have been impossible without it.

The book is designed so that readers who did not major in robotics can still understand the subject. Critchlow recognized that the field of robotics attracts and involves people from a variety of disciplines and wrote to the whole audience. Nearly any engineering major would find the section on analysis of robot arm links interesting and lucid, even though it uses advanced analysis tools like Denavit-Hartenberg matrices.

In my estimation, the book was written for the junior and senior levels of college and is for those people who want to familiarize themselves with robotics or those who intend to become involved in robot applications. Critchlow explains robots from a design standpoint so that the reader can understand why robots exhibit certain characteristics. He explains features that researchers are currently developing and what needs these features will serve. For instance, a factory of the future will have robots that are programmed "off line" directly from CAD (computer-aided design) data so that programming does not take up valuable production time. For off-line programming to become practical, hurdles (collisions, for example) must be overcome. The author describes these problems in detail.

Critchlow reviews research efforts by corporations and universities. The results describe an exciting array of mobile robots, advanced controls and sensors, and language developments that include artificial intelligence.

The references at the end of all chapters indicate that each section is based on extensive research. A reader could use this book as a complete reference resource to locate original papers on robotics topics (such as works of Denavit and Hartenberg), even those that were written early in the robotics era and may now be hard to get. Extensive excerpts or summaries are taken from the refer-

(continued)

ILLUSTRATED BY DAVID GOTHARD

ences and more than support the author's statements. Many of the illustrations are also taken from these references.

Critchlow's unusual and refreshing introduction to robotics begins with European mechanical developments in the 1700s and mentions Karel Capek's coining the word "robot" in 1921. By doing this, Critchlow shows that many basic ideas used in robotics, like mechanical-cam programming, existed for hundreds of years before the word "robot" came into existence.

The author discusses kinematic analysis using homogeneous matrices and, as an exception to the purpose of an introduction, goes on to give numerical examples of their use that are excellent. A reader will immediately see the complexity involved and how maximum performance is demanded from a control computer. Compliant end effectors and end-of-arm tooling schemes are described (compliant tooling offers several advantages despite the added complexity). Mechanical power-drive mechanisms are explained in terms of how they are specially suited to the rigorous needs of robots. Hydraulic, pneumatic, and electric drives are detailed.

Microprocessors are introduced briefly using the 8080 as an example. The reader is given definitions of some of the terminology; fortunately, Critchlow reviews logic gates before moving on to describe microprocessor programming and architecture.

Software capabilities are detailed for several commercial robots. I have seldom seen this much data on the characteristics of robot programming. A total of 14 language systems are reviewed, including VAL, a structured language.

Sensors are evaluated in terms of the signals they produce, how they operate, and the best uses to which they can be put. Vision sensing is introduced in an especially thorough manner in a chapter of its own. Critchlow provides extensive examples of elementary mathematical-analysis methods. You can see for yourself how lines and edges are identified in an image and how their slope and intercept values are determined. Because vision algorithms are complex and quickly exceed the scope of an introduction, the reader is sent to the references that appear at the end of each chapter for more information. But by this time you will know what you want to learn more about and where to find further information. Vision, undoubtedly one of the more important sensing methods, remains largely undeveloped. The reader is shown what vision systems are capable of doing now and what capabilities remain to be developed.

ERRORS

The book contains several errors that you should be prepared to recognize and ignore. I will describe two so that you can sense their nature. (Other small errors such as incorrect references to figures were obvious and not significant.) Though the errors described here do not

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destroy the book's value, they limit its audience to those who wouldn't be misled by them.

The chapter on controls analysis contains a significant error that would certainly confuse the uninitiated. Beginning engineering students would be confused by reading that feedback forces the output of a closed control loop to be equal to its input (that is, their ratio is unity), then seeing the classic development of the closed-loop transfer function. The transfer function, $G(s)/(1+G(s)H(s))$, equation #4 on page 168, is correctly given as the ratio of output to input and is clearly not equal to unity as stated earlier. If the author has an explanation for the differences this literal interpretation of his writing brings to light, he does not say. I can imagine the number of questions a group of students would have about this discrepancy.

I found another error in an extensive description of the General Motors Consight vision system. The Consight system, as described on page 374, was said to be able to accurately measure the height of a part on a conveyor belt even though only a linear diode array camera was being used. Further, the system was described as a two-dimensional system that could provide both a part's height and location on a conveyor belt.

I checked the original reference and found that the Consight system did provide 2-D silhouettes but did not provide height data; it only detected height in finding the outline of the part. I learned enough from Critchlow's writing about solid-state cameras to find this anomaly. In fact, I found it worthwhile to look beyond the errors to appreciate the wide range of information offered in this book on advanced robot controls, software, sensors (especially vision), and applications. The author's work represents a worthy effort, though the errors are annoying.

The book offers a good overall view of the robotics field for someone who wants either a light introduction or a starting point that gives detailed references to original works in robotics and related fields. To me, the most interesting portions of the book are its sections on kinematics and analysis of vision problems. Although errors are significant, they would affect only a fraction of the book's potential audience.

Larry Clark (8103 Thornewood Dr., Hixson, TN 37343) is involved in robotics applications development and teaches robotics after-hours as an adjunct professor at Chattanooga State Technical Community College. His hobbies include building microcomputers and working with a FORTH compiler he wrote.

THE MICROCOMPUTER IN CELL AND NEUROBIOLOGY RESEARCH

Reviewed by David A. Price

The Microcomputer in Cell and Neurobiology Research presents advice for biologists who want to use microcomputers to control experiments and analyze the results. Although

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Inquiry 224

biologists have long used minicomputers and mainframes for these purposes, the advent of microcomputers and lab-oriented microcomputer peripherals (such as high-speed analog-to-digital converters and video "frame grabbers") has made laboratory automation less costly and more convenient. R. Ranney Mize, the editor, selected a diverse range of application areas, with chapters written by researchers who have implemented microcomputer systems for their own labs. They have practical knowledge to share, but their contributions vary widely in quality.

The application areas covered include light and electron microscopy, morphometry (measuring the sizes and shapes of cells and organelles), serial section reconstruction (drawing the original three-dimensional form of an object based on a series of two-dimensional tissue slices), image analysis, and electrophysiology (recording electrical activity in the nervous system). In each of these areas, the potential contribution of lab computers is inestimable. Morphometric analysis, for example, is highly tedious work if the researcher must rely on manual methods. One typical approach is to trace a picture of a cell, cut it out, and weigh the cutout—an approach that one of the authors describes as "exhausting." With a video display or a digitizing tablet, the researcher can partly automate the process, thereby making morphometric information not only less costly but also more accurate.

Researchers using autoradiography (that is, tracing blood flow and other activity using radioactive solutions in animal bloodstreams) have benefited from image-analysis systems. (An autoradiograph is a photographic print of a slice of tissue, with varying levels of gray for varying concentrations of radioactive solution.) After using a video camera or a scanning densitometer to put an autoradiograph into a computer, a researcher can make the gray levels easier to distinguish by having the computer assign "false colors" to each of the gray levels and then displaying the autoradiograph on a color monitor. The researcher can then compare different autoradiographs either visually or with precise, computer-generated statistics.

RESEARCHERS WRITING FOR RESEARCHERS

Because a large number of researchers contributed to the book, it does not focus exclusively on a particular machine; systems described in the book are based on the Apple II, the IBM Personal Computer, the DEC LSI-11, and many other microcomputers. The choice of languages, similarly, includes assembly, BASIC, FORTRAN, FORTH, and C. Most of the contributors describe in precise detail the hardware and software they used to build their systems, as well as the considerations that led them to choose as they did.

The fact that the authors are researchers writing for other researchers has both good and bad effects. A good effect is that their point of view differs sharply from a computer specialist's: The authors place a higher value on simplicity and practicality than on impressive specs. (Some

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A SIGHT FOR SORE EYES

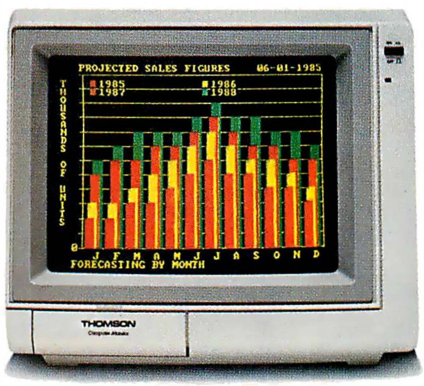
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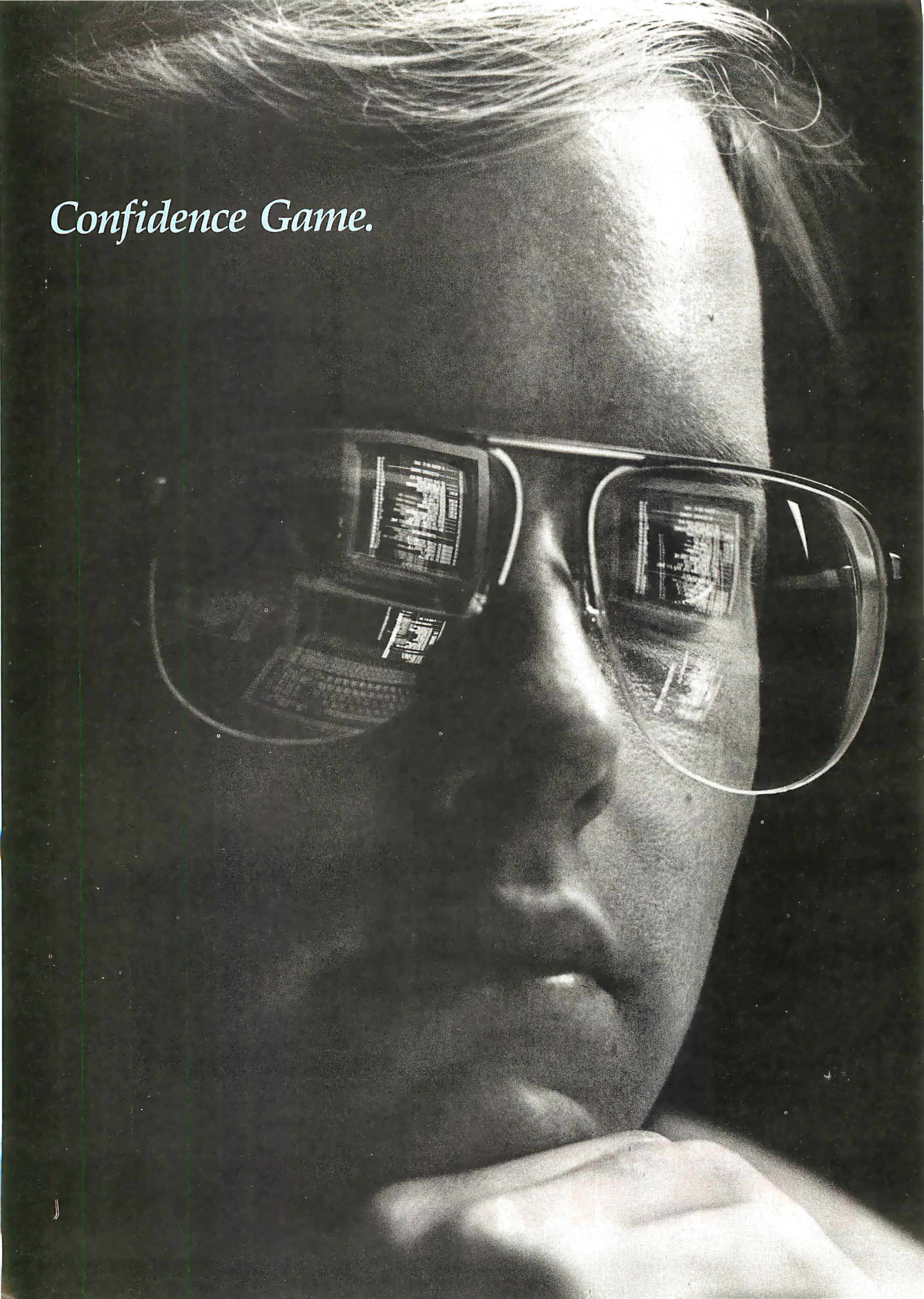
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exceptions stand out, though; a handful of the writers are obviously dazzled by fine technical differences of questionable importance.) Another good effect is that each author provides an extensive bibliography to which readers can refer for further information about algorithms, lab techniques, and equipment. A bad effect is that the text, like most scientific writing, has many awkward moments; the passive voice reigns supreme.

The topics covered are especially well chosen because they not only relate to a variety of applications but also present a variety of engineering problems. The chapters on microscopy and morphometry describe some challenging problems of pattern recognition. The parts covering serial section reconstruction show how some programmers have tackled the representation, manipulation, and display of three-dimensional line drawings. The chapters on autoradiographic image analysis discuss various ways to digitize an image and enhance it. Sections on electrophysiology focus on numerical and graphic analyses of electrical signals. Others provide helpful descriptions of algorithms, and one chapter even includes a lengthy BASIC listing.

Many of the contributions are excellent. The chapter by Sing and Salin, for example, provides a clear overview of popular computer languages and the issues involved in choosing a language for lab use. The chapter on hardware selection by Poler, Akeson, and Flaming includes a useful discussion of technical support; it gives a much-needed warning of the fact that computer dealers are generally unfamiliar with the special requirements of laboratories. The chapters on autoradiographic image analysis are consistently first-rate, as is the chapter by Park on neurophysiological recording.

FLAWS

Some of the contributions, however, fall short. The first chapter, intended as an introduction to microcomputer hardware, says little of importance to researchers. Giving short shrift to the vital topic of interfacing, it consists mainly of a daunting discussion of bus and processor architectures. Some contributors present long and boring recitals of technical data ("The 9845B has dual 16-bit NMOS-II microprocessors, 187 KB of RAM memory, a medium-resolution graphics screen. . .") as a substitute for insight and analysis.

A more serious difficulty is that several of the contributors wrote article-length advertisements, in essence, for products in which they appear to have a proprietary interest. Although the developers of a product are, of course, suited to describe it for interested users, the possibility for abuse is obvious. First, the writer (or editor) does not alert the reader to the pertinent facts. Unless you read the material carefully, you might not realize that the author who is lauding system X also happens to own the company that sells it. When an author has a commercial interest in a product, he or she should say so forth-

(continued)

rightly. Even if the writer is candid about the shortcomings of the product, a reader deserves to know about the potential conflict of interest.

Second, the problem is worse because the offending authors in this book give one-sided, congratulatory views of their products. Their chapters are sprinkled with such adjectives as "powerful," "user-friendly," and "ideal." One author, after describing a system based on a severely dated and now almost unknown microcomputer and on a nonstandard operating system, informs the reader unblinkingly that the system "defies obsolescence."

The book is also marred by some unfortunate omissions of important topics. It gives little attention to managerial issues—for example, deciding whether to write one's own lab software, hire a programmer, or buy a canned package. It omits any discussion of software testing, which is vital in a laboratory because mistakes are costly and often hard to detect.

These flaws aside, *The Microcomputer in Cell and Neurobiology Research* is a worthwhile source of information for researchers with an interest in bringing microcomputers into their laboratories. For researchers considering so substantial an investment, every source of information should be welcome.

David A. Price (57 Roseland St. #2, Somerville, MA 02143), formerly a programmer in physiology and neurobiology laboratories, is a third-year law student at Harvard University.

DATA BASE MANAGEMENT
Reviewed by Joseph A. Benderavage

Databases grow slowly, often over a period of years. Plan one to meet the needs of your organization, for both today and the next decade. This is the underlying principle of *Data Base Management* as seen by the authors, Fred R. McFadden and Jeffrey A. Hoffer. They describe very complete, detailed design rules that are easy to follow. They cite methodology for top-down planning developed by IBM, and they frequently refer to that company.

Database Design

Lack of standardization for semantic controls (commands), among other reasons, led to a conference that laid down guidelines for designing network databases. The Data Base Task Group (DBTG) of the Conference of Data System Languages (CODASYL) formulated the principles listed in the book. All manufacturers, with the exception of IBM, tried to meet CODASYL's specifications. Relational databases, on the other hand, lack uniform index-maintenance procedures and process data one file at a time, not one record at a time. The startling admission that the authors do not know how a relational database implements relationships surfaces amid an ocean of specific and precise definition.

(continued)

Many of the rules in this book are for designing databases, yet there is a reference to using software programs to accomplish this. The authors go to great lengths to identify the symbols and data input for the Data Designer program. They also include a list of costs and benefits that would be useful in the investigative phase of systems analysis and design.

The choice of software for management of data is of paramount importance to design. Although a database management system (DBMS) requires many more steps than a conventional file-processing system to perform a simple task, and although input/output (I/O) operations are slower, McFadden and Hoffer assert that general productivity will be higher. Usually a DBMS has a control system and a storage system, and it interfaces with user programs, compiled representations of data (called schemas), and access methods. This complexity is revealed in an intricate illustration that describes the loading of management-system components connected by a linkage editor into the main memory of a computer. It also shows the communication that occurs between a user program and its schema and, consequently, its data definitions. The authors explain the central role of the data dictionary/directory and its link with schema at length. Many example schemas are mapped out; so too are subschemas, which give customized views of a database and are independent of application programs.

File Design

McFadden and Hoffer's helpful rule of thumb for designers suggests that an index referencing more than 10 percent of the records in a file will not work as efficiently as a complete sequential file scan. A compact table, impressive in its coverage and scope, presents guidelines for identifying secondary and primary keys to further assist in file design. The authors' explanation of random access to ISAM (indexed sequential access method) files is very lucid, as is that for hashing algorithms and hashed file designs. I discovered that the access-speed hashing algorithm was 80 percent of maximum access speed, a factor certain to influence your choice of access method.

The chapter on data models (hierarchical, relational and network, and the hybrids) clearly demonstrates the reduction of complex user views to a set of small data structures. This is the strongest part of the book. Normalization is extensively documented and lists the criteria for first, second, and third normal forms and beyond.

A useful tip I gleaned is the 80-20 rule, which declares that 20 percent of all data items accounts for 80 percent of I/O operations.

The authors make few concrete analogies. I appreciated one that introduced the grouping of intrarecord data structures with a folk saying: Don't put all your eggs in one basket. Another analogy compares inverted lists with the task of consulting a library file catalogue.

McFadden and Hoffer refer to the concept of virtual

(continued)

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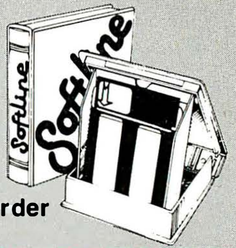
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Genoa's Galaxy™ Systems are more highly evolved. So not only do they outperform competitive systems, but using them is actually something that can be done by an ordinary human.

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Our software is what makes the difference between our systems and everybody else's. And it's designed to help you use the system easily in either of two modes. Namely, menu-driven or batch file.

The menu mode operates true to its name, with menus showing all the commands you have to choose from. Plus, there are multiple window displays that show execution status, on-line help with examples and how-to's, even an editor just in case you make a mistake in selecting a command. And there isn't a thing you can't do from the menu mode because it's comprehensive.

You'll want to use the batch mode for routine operations though, because it allows you to create a "file" to contain those operations and run them automatically, just by hitting a few keys. You can create your batch files easily, too, using the same commands as the menu mode.

But probably the best example of just how downright civil the Galaxy systems can be is our auto backup. You just preset the time and the desired function, and the system does the rest. Automatically.

No other tape backup systems, by the way, operate this simply. In fact, if you saw what passes for "user-friendly" these days, you'd be horrified.

The features all tape backups should have. But don't.

Beginning with our ease of installation.

Before you make your first backup—which is the right time to do this—our installation software checks your disk configuration to make sure your tape drive will run at top speed. And it checks the entire system to guarantee it will perform as promised. Elapsed time? About 7 minutes.



The IBM®-compatible Genoa Galaxies are available as internal or external versions of ¼" streaming tape or cassette models. (External cassette not shown).

No competitive system offers anything like it.

Another thing you can do is abort any command at any time. So you don't have to sit through a 20-minute file-by-file restore just because you hit the wrong key.

Something else not everybody can do.

You can also do a file-by-file restore from an image backup. Now you'd think everybody could do this, but no. It's important though, because if you've made an image backup (as most people do since it's so fast), you want to be able to get back the one file you need rather than all the files you don't. Hence, file-by-file restore from an image backup.

But whether it's a couple of files or a complete image, you'll be pleased to know you can restore to any storage device, thanks to Galaxy's interchangeability feature.

Multiple backups on the same tape—even from multiple sources like a floppy or another hard disk—aren't a problem either. The system simply starts recording where the last backup ended.

Or you can use multiple tapes to back up very large files. The system will just let you know when it needs a new tape. And as long as you have enough tape, you can backup as much as you like.

We also perform crc error checking constantly. We can back up a 20Mb disk in just over 4 minutes. And we're network compatible. Some of our competitors can do some of these things, some of the time.

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Surprisingly, the Galaxies cost somewhat less than tape backup systems that offer less. Which includes all of them.

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The Genoa Galaxy Systems. The most civilized tape backup in history.

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storage frequently, but they explain it rather cursorily, mainly with diagrams.

Program Languages and Illustrations

Why not program in English? Excessive overhead and absent update facilities in network-database processing constitute the predominant reasons for not doing so. Nonprofessionals currently interacting with a database may use codified query languages, but they still must know syntax and vocabulary. The authors use pseudocode in a great number of sample programs, while they use a variety of languages for the algorithms throughout the latter part of the book, especially programs for the hierarchical database systems IMS, DL/1, and System 2000/80. However, the authors affirm a trend toward natural languages.

Each chapter includes an introduction, narrative, summary, exercises, and a review filled with stimulating problems and questions. A lengthy bibliography closes each chapter, while a cumbrous index completes the book. Highly visible symbols in the margin of the text keynote case examples. A supplementary classroom package available to instructors contains answers, teaching suggestions, questions, and transparencies. Another supplement contains case studies for course projects.

Reference Tool

Must textbooks always be dull and tedious? While parts of this book read easily, much of it is slow and dry. Nevertheless, the style is smooth, even-tempered, unequivocal, and consistently serious (except for a startlingly funny simile likening a data model diagram to an explosion at a spaghetti factory).

The authors tested this book in an introductory course on database management and in management programs. Generally, they provide reasons for their teaching method; they itemize, prioritize, and categorize the logic of doing things their way. The text is chock-full of definitions, with new terms conspicuous in boldface print. They define buzzwords, Latin phrases, and ambiguous terms in parentheses and often use outline formats. Examples and "what if" situations abound, including a definition of "real world" as one of the realms of abstraction. They list many advantages of the personal computer and ascribe a positive outlook to it in data-management strategy.

Data Base Management begins on a dense, abstract, and theoretical level. If you are in tune with the authors' idiom, you will derive the full worth of the book. While it is a textbook for upper-division university and graduate students as well as data-processing managers, system designers will find the tome a valuable tool that contains numerous relevant cross-references. It incorporates sound advice and practical suggestions for consultants, too. ■

Joseph A. Benderavage (POB 1974, Peterborough, Ontario K9J 7X7, Canada), a member of the Royal Astronomical Society, is a freelance book reviewer published frequently in Canadian computer magazines.

This is for all the power users technologies before they

Other than Steve Wozniak and Jonathan Rotenberg, there are probably only 2,998 personal computer users who qualify as trend setters. They're the people who owned Apples® when everyone else thought Apple® was a record label. People who were called hackers when a hacker was someone no one wanted to play golf with.

However many of you there are, this ad is for you. It's been designed and written to introduce you to a new technology without using superlatives or words like revolutionary. (We're saving those words for future ads targeted at the general consumer.)

The new technology is called the Softstrip™ System. This ad tells you what it's all about.

THE SOFTSTRIP SYSTEM ENCODES DATA ONTO PAPER.

Softstrip technology allows text, graphics, even digitized sound to be encoded on a strip of paper. Providing an alternative to magnetic media and telecommunications for the recording, distribution and retrieving of information.

These data strips, each a structured pattern of black and white rectangles that look something like a condensed bar code, can be encoded with special software and read with a scanning device called the Cauzin Softstrip System Reader. The reader optically scans the strip, translates its contents into 8-bit code and feeds it into a personal computer's serial or cassette port, enabling automatic, error-free entry of printed data without using a keyboard.

One Softstrip data strip, typically ⅝" x 9½", can contain up to 5,500 bytes of information. (For example, you could fit this entire ad on two strips.)

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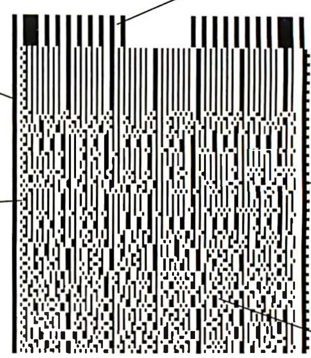
If you want, you can generate strips that can be reproduced on a copier or versions that can't be. Either way, any data strip, whether it's printed in a newspaper, magazine or personal letterhead, can survive pen marks, scratches, even coffee stains.

Basically, anything you can put on a magnetic disk you can put on a Softstrip data strip, which should suggest numerous application possibilities.

Starting in the next two months, data strips will appear in magazines, journals and books. These strips will contain program listings, tables of contents, new product demonstrations and data.

Eventually, strips may be used for everything from bank statements to sheet music.

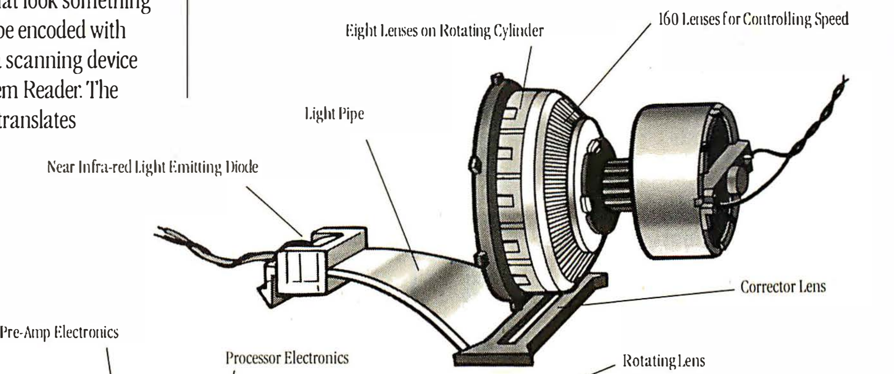
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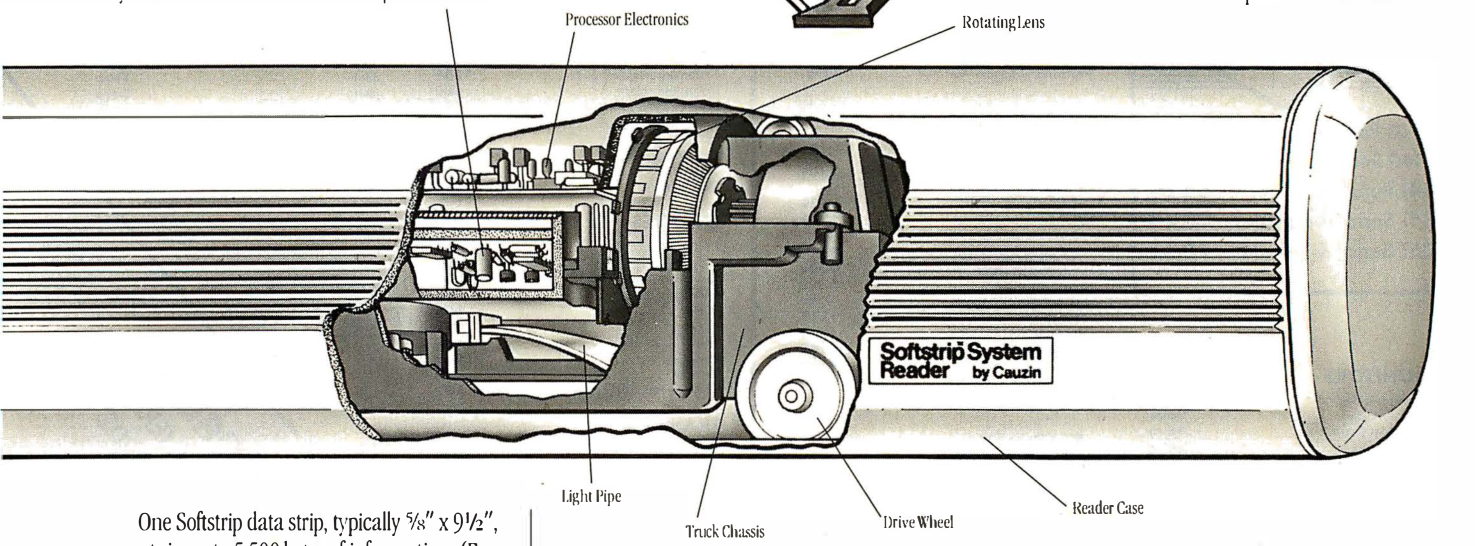


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Strips encode data bit by bit using highly structured optical patterns. The bits are each composed of two rectangles called di-bits. They function as optical on/off signals. White/black equals 1. Black/white equals 0.

Data is organized in lines. Each line, between 0.01 and 0.04 inches high and from 0.5 to 0.76 inches wide, contains from two to six bytes of data. Line width and height are varied depending upon the quality of the paper and printing process. The reader scans each data line with a series of raster scans 0.0025 inches apart providing between four and sixteen scans per line.





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A close-up view of a strip reveals five distinct sections. The header (1) at the top tells the reader the number of bytes in a line, the height of each line, and the paper to ink contrast level. Running vertically down the sides of the strip are the startline (2), the checkerboard (3) and the rack (4). They identify the boundaries of every horizontal line to be read. They also work in tandem to feed the reader alignment information.

Contained within the body of the strip, between the checkerboard and rack, is the file's data area (5).

Strip data accuracy is checked and error correction is provided by parity bits at the beginning and end of every data line, as well as by a strip checksum. There is also an optional 16 bit CRC. Combined, this design results in an undetected bit error rate of less than one bit error per 10,000,000,000 bits.

IT TOOK GUTS TO BUILD THE READER.

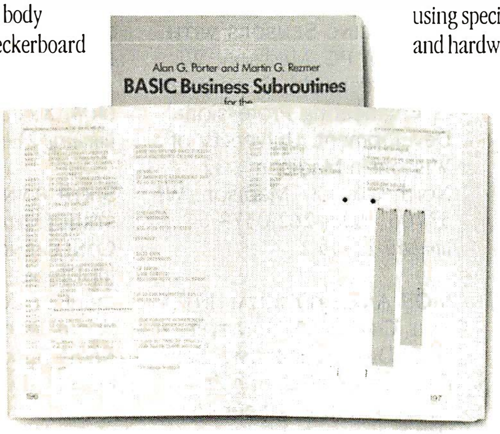
Rated for 25,000 reads, the reader is an equally impressive technology. It's composed of two key components: the case and the truck. While the case sits still, the truck moves uniformly down the length of the strip making a complete scan of the strip's di-bit lines every 0.0025 inches.

As the truck moves down the strip, it tracks its own lateral movement within five microns. Alignment is controlled by two servo mechanisms. As the truck moves, it illuminates the area to be scanned using near infra-red light beamed through a light pipe. (The infra-red technique permits the reader to see through colors, stains, and spills.)

The reader's optical scanning system, containing eight rotating cylindrical lenses and an aspherical corrector lens, forms an F.12 optical system with a depth of field between 0.05 and 0.08 inches. A set of 160 additional cylindrical lenses on the rotating lens allow the system to control scanning speed.

Inside the reader, the mechanical system uses six AGMA-7 high precision plastic molded gears to provide very accurate truck movement. One gear system even allows for a 4000 to 1 angle reduction with no backlash for corrector lens alignment.

A TMS 7040 8-bit processor and Cauzin's own custom VLSI chip provide reader logic, control and communications using four nested phase locked loops and several hardware and software servos. The reader transmits data to the host at 4800 baud burst rates with throughput of 1500 baud.

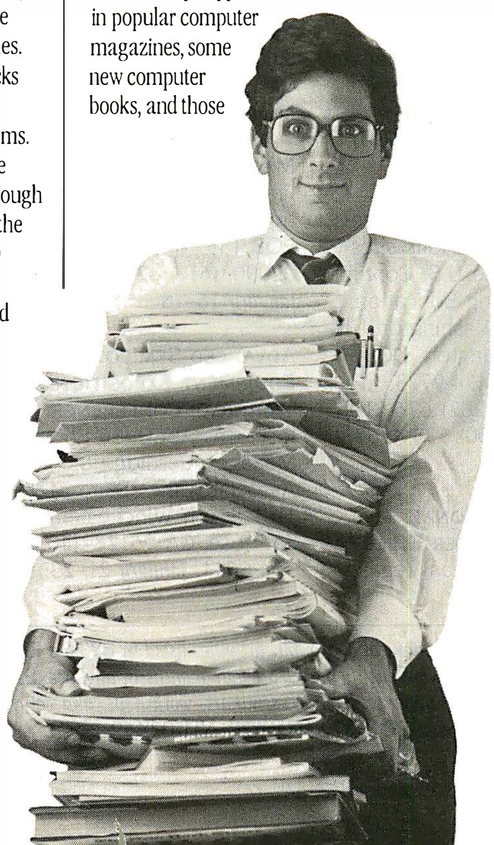


HOW TO CREATE YOUR OWN STRIPS.

There are two ways to create Softstrip™ data strips. For large volume and greater density– up to 5500 bytes per strip – a film negative is created using special Cauzin software and hardware. This is ideal for book, magazine, newsletter, data base and commercial software publishers who can reproduce a strip in volume using web, offset, gravure or similar processes.

For personal or business applications, 500 to 1000 byte strips can be generated using Cauzin licensed software on dot matrix printers; up to 3400 byte strips can be generated using other Cauzin licensed software and laser printers.

In the next few months, you should start to see data strips appear in popular computer magazines, some new computer books, and those consumer ads we told you about earlier. They'll look exactly like the working strip you see here, a medium density strip with an ASCII text file on it.



Of course you'll be able to purchase a reader at most computer dealers. They'll be selling for about $200.00. Contact your dealer soon for a demonstration. Or call us directly at 203-573-0150.

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E·V·E·N·T Q·U·E·U·E

January 1986

INTRODUCTION TO DIGITAL SIGNAL PROCESSING & FILTERING; MINI- AND MICROCOMPUTER CONCEPTS; AND MICROPROCESSOR HARDWARE AND SOFTWARE—AN INTRODUCTION, Milwaukee, WI. John T. Snedeker, University of Wisconsin-Milwaukee/Extension, 929 North Sixth St., Milwaukee, WI 53203, (414) 224-4193. *January*

MICROCOMPUTER AND COMMUNICATIONS SEMINARS, various sites throughout the U.S. Center for Advanced Professional Education, Suite 110, 1820 East Garry St., Santa Ana, CA 92705, (714) 261-0240. *January*

MICRO SHOWS AND FLEA-MARKETS, Philadelphia, PA, Secaucus, NJ, and Boston, MA. Ken Gordon Productions Inc., POB 13, Franklin Park, NJ 08823, (201) 297-2526. *January*

ROBOTICS: FUTURE TRENDS IN THE 1980S, Des Moines, IA. The Des Moines Center of Science and Industry, 4500 Grand Ave., Des Moines, IA 50312, (515) 274-4138. *January*

COMMUNICATIONS/MICROCOMPUTER CURRICULUM, various sites throughout the U.S. Datapro Research Corp., 1805 Underwood Blvd., Delran, NJ 08075, (800) 328-2776. *January–February*

INTENSIVE SEMINARS FOR PROFESSIONAL DEVELOPMENT, Boston, MA, area. Kathy Shaw, Office of Continuing Education/Higgins House, Worcester Polytechnic Institute, Worcester, MA 01609, (617) 793-5517. *January–March*

SYMPHONY SEMINARS, various sites throughout the U.S. Automated Digital Offices, 4555 MacArthur Blvd., Washington, DC 20007, (202) 337-1393. *January–March*

COMPUTER COMPETENCE SEMINARS, Boston, MA, area. Boston University Metropolitan College, 755 Commonwealth Ave., Boston, MA 02215, (800) 255-1080; in Massachusetts, (617) 738-5020. *January–April*

COMPUTER SHORT COURSES, various sites throughout the U.S. Integrated Computer Systems, 6305 Arizona Place, POB 45405, Los Angeles, CA 90045, (800) 421-8166; in California, (800) 352-8251 or (213) 417-8888. *January–April*

SYSTEMS SEMINARS, various sites throughout the U.S. Ken Orr & Associates Inc., 1725 Gage Blvd., Topeka, KS 66604-3379, (800) 255-2459; in Kansas, (913) 273-0653. *January–April*

MICROCOMPUTER/ENGINEERING COURSES, various sites throughout the U.S. Continuing Engineering Education, The George Washington University, Washington, DC 20052, (800) 424-9773; in Washington, (202) 676-6106; in Canada, (800) 535-4567. *January–May*

1986 INTERNATIONAL WINTER CONSUMER ELECTRONICS SHOW, Las Vegas, NV. Consumer Electronics Shows, 2001 Eye St. NW, Washington, DC 20006, (202) 457-8700. *January* 9–12

INTERFACING SENSORS WITH THE IBM PC, Madison, WI. E. K. Greenwald, Department of Engineering Professional Development, University of Wisconsin-Madison, 432 North Lake St., Madison, WI 53706, (608) 262-0573. *January* 13–15

MOS ANALOG/DIGITAL INTERFACE CIRCUIT DESIGN FOR VLSI DIGITAL SYSTEMS, San Francisco, CA. Continuing Education in Engineering, University of California Extension, 2223 Fulton St., Berkeley, CA 94720, (415) 642-4151. *January* 13–15

DATA RECOVERY: WHAT TO DO WHEN IT ALL GOES WRONG, Phoenix, AZ. Independent Computer Consultants Association, POB 32115, Phoenix, AZ 85064. *January* 14

MACWORLD EXPOSITION, San Francisco, CA. World Expositions, Mitch Hall Associates, POB 155, Westwood, MA 02090, (617) 329-7466. *January* 16–18

ADVANCED SEMICONDUCTOR EQUIPMENT EXPOSITION & TECHNICAL CONFERENCE, San Jose, CA. ASEE '86 Show Manager, Cartlidge & Associates Inc., Suite M259, 1101 South Winchester Blvd., San Jose, CA 95128, (408) 554-6644. *January* 21–23

WRITING BETTER COMPUTER SOFTWARE DOCUMENTATION FOR USERS, Research Triangle Park, NC. Trish Stolton, Department of Continuing Education, Georgia Institute of Technology, Atlanta, GA 30332-0385, (404) 894-2547. *January* 21–23

SIXTH ANNUAL FLORIDA INSTRUCTIONAL COMPUTING CONFERENCE, Orlando, FL. Jill Draper, Florida Department of Education, Educational Technology Section, Knott Building, Tallahassee, FL 32301. *January* 21–24

ANIMATING ESCHER WITH COMPUTER GRAPHICS; SPECIAL EFFECTS; AND FRACTALS, COMPUTERS, AND DNA, New York, NY. Gideon Nettler, Department of Mathematics and Computer Science, Montclair State College, Upper Montclair, NJ 07043, (201) 893-4294. *January* 22

MAKING SENSE OF DATA COMMUNICATIONS; T-1 FACILITIES AND NETWORKING, Orlando, FL. Timeplex Inc., 400 Chestnut Ridge Rd., Woodcliff, NJ 07675, (201) 391-1111. *January* 22–23

1986 MEASUREMENT SCIENCE CONFERENCE, Marriott Hotel, Irvine, CA. Dennis Pinnecker, Measurement Science Conference, POB 1294, Corona, CA 91718, (714) 632-3923. *January* 23–24

COMMUNICATIONS NETWORKS '86, Washington, DC. CW Conference Management Group, Box 880, Framingham, MA 01701, (800) 225-4698; in Massachusetts, (617) 879-0700. *January* 28–30 ■

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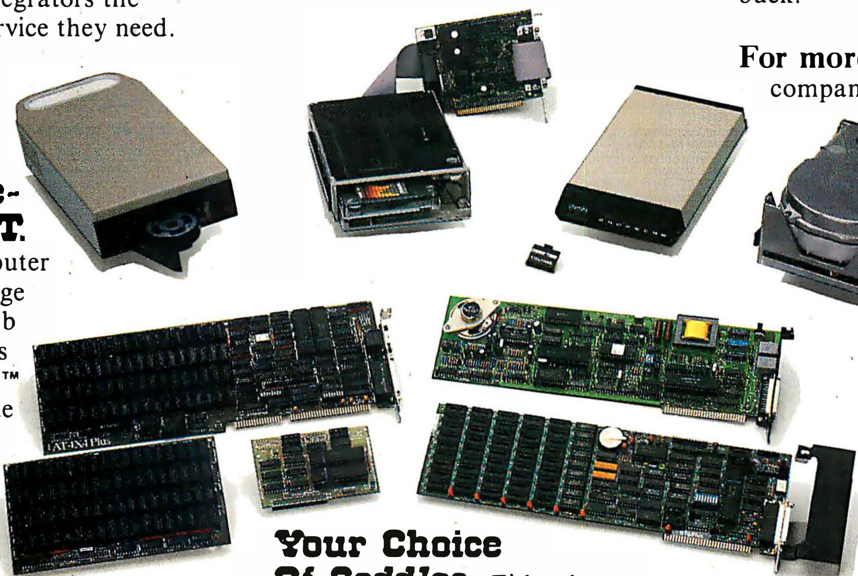


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*Infoworld Sept. 2, 1985, Page 1.

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Micro Sci Floppy Controller	55.00*	(2.50)
▶Paradise Mac 10MB Hard Drive Subsystem	750.00*	(16.20)
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▶PC Network 140K External Drive for Apple IIc	95.00*	(2.50)
Rana Elite I 163K Drive	225.00*	(5.00)
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Tecmar 10MB MAC Drive	999.00*	(21.58)
Tecmar 5MB MAC Drive Upgrade	1,235.00*	(26.68)

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Prometheus 1200A Low Cost 1200 Baud Internal Modem for Apple II	276.00*	(6.00)
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Microsoft Premium Softcard IIe	243.67*	(2.50)
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Quadram APIC/G Graphics Interface	62.00*	(2.50)
Quadram e RAM-80	88.00*	(2.50)
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Thunderware Thunderclock	104.00*	(2.50)

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Sony MAC Diskettes (Box of 10)	22.95*	(1.50)

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▶Central Point Copy II PC	20.00*	Oasis The Word Plus	75.00*
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▶Tandon TM 100-2 Full Height DS/DD Drives	93.00*	(2.20)
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▶Teac FD 55-B Half Height DS/DD Drives	90.00*	(1.94)
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▶PC Network Replacement 130 Watt IBM-PC Power Supply—Gives your PC the same Capacity as an XT Good for add in Tape Drives (without need for a piggyback unit) and large capacity disk drives.	76.00*	(2.70)
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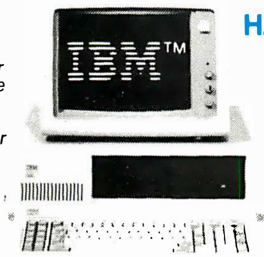
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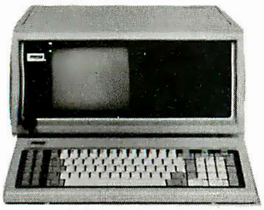
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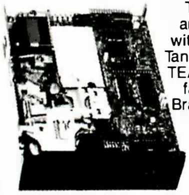
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Features

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CREATING REUSABLE MODULES
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PROGRAMMING INSIGHT: EASY 3-D GRAPHICS
by Henning Mittelbach **153**

THREE BYTE STAFF MEMBERS, Jon Edwards, Phillip Robinson, and Brenda McLaughlin, have put together a preliminary but detailed evaluation of the Atari 520ST. They summarize the hardware of the 520ST as "the 68000 unbounded." Among the features they were impressed with are the quality of video output (though you must choose between monochrome and color), the speed of the disk I/O, and the variety of ports. An unfinished operating system and minimal application software did not dampen their overall impression.

The subject of analog-to-digital conversion is one that Steve Ciarcia returns to every few years. He does this largely so that new readers can learn the basics. For readers who have been around for a while, he also includes the latest conversion interface. This month's column is no exception. Steve discusses the basics and then describes a 16-channel 12-bit high-speed A/D converter.

"Q&A" is a product preview about an integrated software package that combines word processing and file management with a full macro facility and an effective natural-language interface—your Intelligent Assistant. By entering normal English phrases and sentences, you can carry on a conversation with your Assistant and get a lot of information into and out of your database. Jon Edwards provides a sample session in "Q&A," discusses some of its drawbacks, and compares it with other natural-language database products.

Last month, Jonathan Amsterdam began a three-part article on a compiler for his high-level language called SIMPL. This month, he describes the part of the compiler that handles procedures and functions, also known as routines. The routines of SIMPL are similar to those of Pascal, and like most routines, they're useful for programmers but difficult to compile.

Large software projects can be undertaken by simply reusing the same modules of code in different programs. Modula-2 imposes some restrictions to this method, and Namir Clement Shammas, author of "Create Reusable Modules," offers a program strategy as a solution. The strategy involves the creation of capsule editors, the advantages of which include customization of programs, lowered costs, and increased reliability.

Creating three-dimensional graphics on microcomputers has been a popular subject with both BYTE readers and authors. In "Budget 3-D Graphics" (March 1985), author Tom Clune looked at the program SURF, which includes such advantages as hidden-line removal and the ability to rotate the plot around three axes. This month we have "Easy 3-D Graphics" by Henning Mittelbach. The author has written a low-cost, three-dimensional graphics program for the IBM Personal Computer, the Apple Macintosh, and the Apple II family.

THE ATARI 520ST

The 68000 unbounded

Editor's note: The following is a BYTE product description. It is not a review—for several reasons. Some of the equipment we received, such as the hard-disk drive, were prototypes, and at the time of this writing, software is scarce. Atari has not yet completed its BASIC interpreter, and the operating system, TOS, remains unfinished. Nonetheless, we are as intensely interested as our readership in new technology, and we feel we have learned enough to share some of the results of our investigations. We began our work on this description as soon as we were able to get a system from Atari. A full review will follow in a subsequent issue.

For many years the public has equated the Atari name with arcade games and joysticks. In truth, the Atari 400/800/XL computer line is technically at least comparable if not better than other 8-bit machines, so it should not be a surprise that the company's latest venture, the 520ST (see photo 1), is a competitive 68000 system. Indeed, we are most impressed with the clarity of the graphics, with the speed of the disk I/O (input/output), and with the 520ST's value.

The system is not without its problems. The desktop is less effective than the Macintosh's, the keyboard has an awkward feel, and the current operating system makes it impossible to switch between high-resolution monochrome and low- or medium-resolution color without installing the other monitor and rebooting. Nonetheless, we are left with a very favorable impression; several software-development languages are already available, including FORTH, Modula-2, and C. With them, you can tap the power of the 68000 at a most reasonable price.

SYSTEM DESCRIPTION

The Atari 520ST is a keyboard computer. Like the Commodore 64 and the Atari 400/800, the 520ST keyboard unit contains the microprocessor, the memory, the video and sound circuitry, and so on. The power supply, disk drives, and monitor are external devices. The 520ST has a variety of ports, but there are no internal expansion slots.

The In Brief box on page 90 summarizes the features of the Atari 520ST. For $799, you get the CPU, a 12-inch diagonal monochrome monitor, and one external single-sided double-density floppy-disk drive. For $999, you get the same system with a 12-inch RGB analog monitor in place of the monochrome monitor (see photo 1). Both systems provide 512K bytes of RAM (random-access read/write memory), a Motorola 68000 microprocessor, MIDI ports with a transfer rate of 31,250 bps (bits per second), a DMA (direct memory access) port with a transfer rate of 10 megabits per second for a hard disk or CD-ROM (compact-disk read-only memory), and much, much more. To be sure, owners will make some sacrifices. The unit does not have an RF (radio frequency) modulator for television output, every peripheral has a separate power supply (wire haters beware), and the operating system currently rests in RAM, stealing over 200K bytes from your workspace. We have summarized other problems below, but almost all are insignificant when you consider what you do get for the money. And rest assured, the system works. Our first system, like most of the first production units, had to have several chips reseated. It now functions properly, and we have not heard of any similar quality-control problems on the latest 520STs.

THE HARDWARE DESIGN

The heart of the 520ST is the MC68000, with its 16-bit data bus and 24-bit address bus, running at 8 MHz (see figure 1). The rest of the system was designed to stay out of the 68000's way. (See the 520ST motherboard in photo 2.)

The Atari design team began work on the 520ST in May 1984. From the start, they had several specific goals in mind. The first was to choose a fast microprocessor and do everything to let it run effectively at full speed. To the Atari team, that meant maximizing bus bandwidth and relegating as

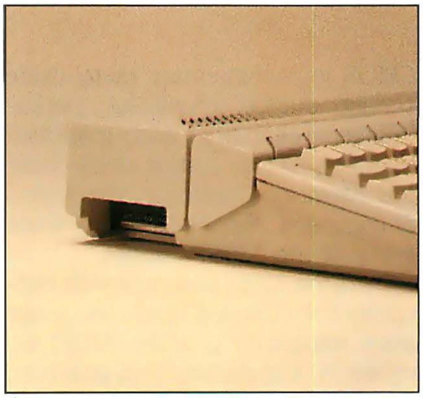
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Jon R. Edwards is a technical editor, Phillip Robinson is a senior technical editor, and Brenda McLaughlin is an associate news editor for BYTE. They can be contacted at BYTE, POB 372, Hancock, NH 03449.

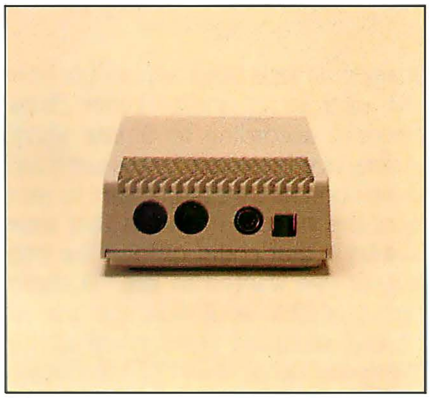
BY JON R. EDWARDS, PHILLIP ROBINSON, AND BRENDA MCLAUGHLIN



(a)



(b)



(c)



Photo 1: *The Atari 520ST, shown here with the color monitor and two single-sided double-density disk drives. (a) On the right side of the keyboard unit are two joystick/mouse ports. (b) On the left is the 128K-byte ROM cartridge port. (c) The rear of the disk drives has specific ports for I/O in and I/O out.*

PHOTOGRAPHED BY PAUL AVIS

many mundane tasks as possible from the microprocessor to other chips. Second, according to Shiraz Shivji, Atari's vice president for research and development, "We didn't want to reinvent the wheel . . . things that were available that could offload the processor—we wanted to use." A direct result of that goal was the use of several standard chips (such as the Western Digital WD1772 for floppy-disk-drive control) and use of custom CMOS (complementary metal-oxide semiconductor) chips for performance, reliability, and manufacturability. All four custom chips—Glue, the Memory Controller, the Video Shifter, and the DMA chip—share many of the 520ST's duties.

Third, the 520ST had to provide high-quality color displays. Finally, the design team wanted to give the 520ST excellent I/O capabilities. That goal is reflected in both the variety of ports that surround the 520ST and in the high speed of the DMA (hard-disk) port.

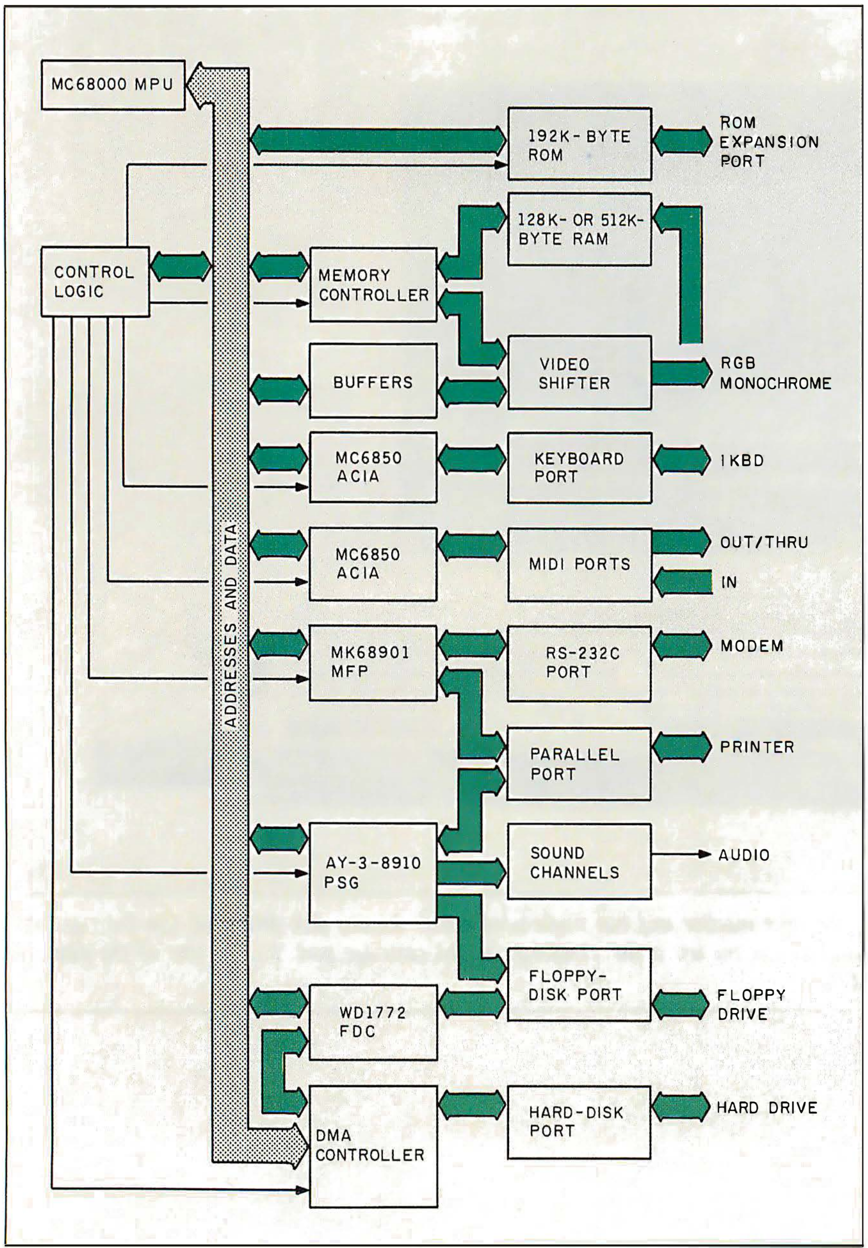


Figure 1: *The system block diagram for the Atari 520ST.*

MEMORY

The 520ST currently includes 512K bytes of RAM and 16K bytes of ROM. The RAM consists of sixteen 256K-bit dynamic RAM chips that are rated at 150 ns (nanoseconds). Atari is already talking about 1-megabyte and 2-megabyte (RAM) versions of this same computer. The 68000 CPU (central processing unit) can directly address up to 16 megabytes of ROM and RAM, but the present Memory Controller chip can only work with 4 megabytes. The circuit board has room, but it will need a slight redesign to use the 1-megabit dynamic RAMs when they become available. (The 1-megabit chips have two more pins than the 16-pin 256K-bit chips they would replace and also would have some of the signals on different pins. This change would require a small modification in manufacturing.)

Memory is configured as five 64K-byte sets of ROM and one configurable bank of 128K bytes, 512K bytes, or 2 megabytes of RAM. (Early in 1985, Atari mentioned a possible 128K-byte RAM version of the ST.) Software determines the ROM configuration. A shadow-test algorithm that loads a Memory Configuration register determines the RAM configuration. When the computer is turned on, this algorithm tries to write to and read from memory addresses unique to the possible configurations.

The memory map is shown in figure 2. The first 2K bytes (lowest address values) are reserved for the exception vector table and the supervisor stack. These 2K bytes—and the I/O space—are protected: They can only be accessed when the CPU is in supervisor mode. Four words of ROM are shadowed at the start of RAM for the reset stack pointer and the program counter.

VIDEO MEMORY

The Atari 520ST offers three display resolutions. The highest resolution is a noninterlaced monochrome 640- by

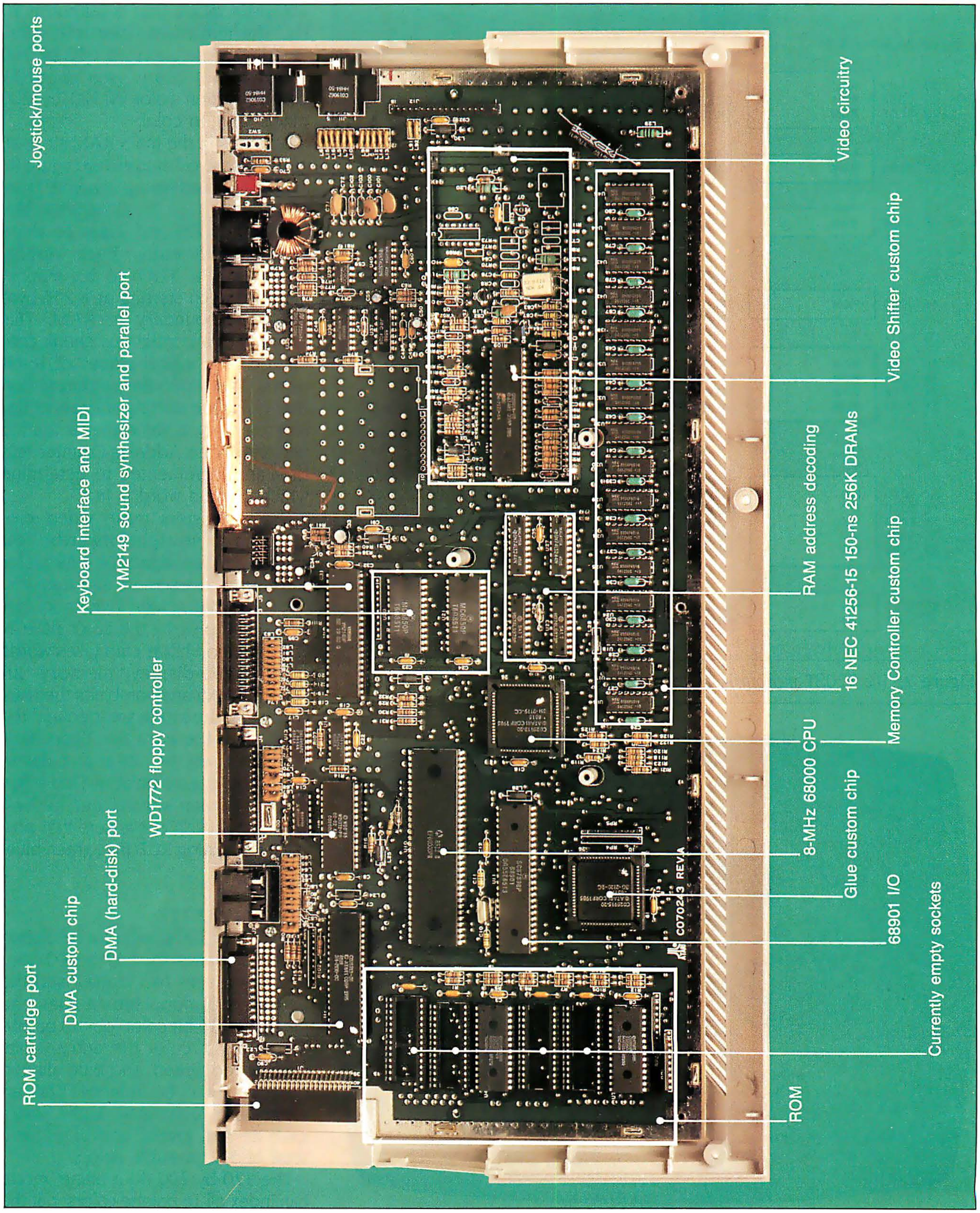


Photo 2: *The Atari 520ST motherboard.*

--ST MEMORY MAP-----

Address	Type	Description
00 0000	ROM	RESET: SUPERVISOR STACK POINTER
00 0004	ROM	RESET: PROGRAM COUNTER
00 0008	RAM	0K-BYTE RAM
•		
02 0000	RAM	128K-BYTE RAM
08 0000	RAM	512K-BYTE RAM
•		
•		
•		
fa 0000	ROM	320K-BYTE ROM
•		
fc 0000	ROM	RESET: SUPERVISOR STACK POINTER
fc 0004	ROM	RESET: PROGRAM COUNTER
fc 0008	ROM	192K-BYTE ROM
fe ffff	ROM	0K-BYTE ROM
•		
•		
•		
ff 8000	I/O	CONFIGURATION REGISTERS
ff 8200	I/O	DISPLAY REGISTERS
ff 8400	I/O	RESERVED
ff 8600	I/O	DMA/DISK REGISTERS
ff 8800	I/O	SOUND REGISTERS
•		
ff fa00	I/O	MC68XXX REGISTERS
ff fc00	I/O	MC68XX REGISTERS

Figure 2: *The 520ST memory map.*



Photo 3: *Low-resolution graphics offer 16 colors in a 320- by 200-pixel array.*

400-pixel mode that is output at 70 Hz. The maximum color resolution, "medium resolution," is 640 by 200 pixels with 4 colors (see photo 3). Low-resolution color is 320 by 200 pixels with 16 colors.

Bit maps in the main RAM store all of the displayed images (see figure 3). A special interleaving scheme, managed by the Memory Controller chip, allows the CPU and video to share memory efficiently. Each display mode uses a 32K-byte bit map in memory, each starting at a 256-byte half-page boundary in RAM. This memory is a contiguous chunk configured as *n* logical planes of 16-bit words. The Video Base Address register holds the starting address of display memory, a value that is loaded into the Video Address Counter register and incremented to determine which plane a word is in.

These registers make video programming straightforward. You choose a mode, select the address for the start of the screen, and then you have a bit-map screen in memory that is affected only by the color palette.

The Video Shifter chip takes words from video-display memory (in general RAM) and combines them according to the mode selected and the position of the word (see figure 4). It then interprets the bits as an index to the color lookup palette. That information is then shifted out to 3-bit digital-to-analog converters that produce the analog RGB (red-green-blue) output.

Color Palette

The 320- by 200-pixel color resolution uses four planes, the 640 by 200 color resolution uses two planes, and the 640 by 400 monochrome uses one plane. The 16-bit color lookup palette has 9 bits of color per entry, 3 bits each of red, green, and blue aligned on low-nybble boundaries. This arrangement generates eight levels each of red, green, and blue, for a total of 512 possible colors.

The 320 by 200 (four-plane) mode can index all 16 palette colors, but the 640 by 200 (two-plane) mode works with only the first 4 palette entries.

The 640 by 400 monochrome mode bypasses the palette, instead employing an inverter for inverse video. The inverter is controlled by bit 0 of palette color 0. Palette color 0 also assigns a border color in multiplane mode and a white or black border in monochrome mode.

A single call to BIOS (basic input/output system) can change the colors in the palette registers. You could show all 512 colors on a single screen by making such calls on the fly. The 520ST does not have any hardware provision for sprites or player-objects, graphics tools that are found in the Commodore 64, Amiga, and Atari 800. It does have bit-blitting, but only in the GEM software.

MEMORY CONTROLLER

Using the data bus efficiently was an absolute priority in the design of the 520ST. The CPU makes frequent use of the bus: The designers noticed that between 30 and 40 percent of program instructions would be store and load types. And the video display needs constant refreshing from memory. After all, in a bit-mapped system such as this, the display on the screen is virtually an image of what is in the RAM chips.

A 68000 running at 8 MHz takes 500 ns for each memory-access cycle. But during the first 250 ns of that time, it isn't looking at the data bus. Instead, it is just setting up the address bus and performing handshaking functions. Shivji explains that his team decided to use memory chips that could be read in a 250-ns slot, and then to put a Memory Controller custom chip between the CPU and memory. The same controller also sits between the Video Shifter custom chip and memory.

During the first 250 ns of the 68000's 500-ns read cycle, the Memory Controller gives the Video Shifter access to RAM. Then, when the 68000 is ready—during the second 250 ns of the read cycle—the Memory Controller turns RAM access over to the CPU. The Video Shifter and CPU keep taking turns. Because the RAM is twice as fast as the microprocessor, the 68000 can run at full speed and read or write to RAM as it desires without disturbing the refreshing of the display. More important, CPU tasks won't be put on hold while the video circuitry makes heavy demands on memory for high-resolution data.

Occasionally, because the 68000 has an asynchronous bus that you cannot lock exactly with the video circuitry, missed cycles will occur. All that happens is that the CPU has to wait one 250-ns cycle, a rare event according to Shivji.

16-BIT WORD					
4 PLANE	PLANE 0	PLANE 1	PLANE 2	PLANE 3	PLANE 0
2 PLANE	PLANE 0	PLANE 1	PLANE 0	PLANE 1	PLANE 0
1 PLANE	PLANE 0	PLANE 0	PLANE 0	PLANE 0	PLANE 0

Figure 3: *Organization of bit-plane data in memory.*

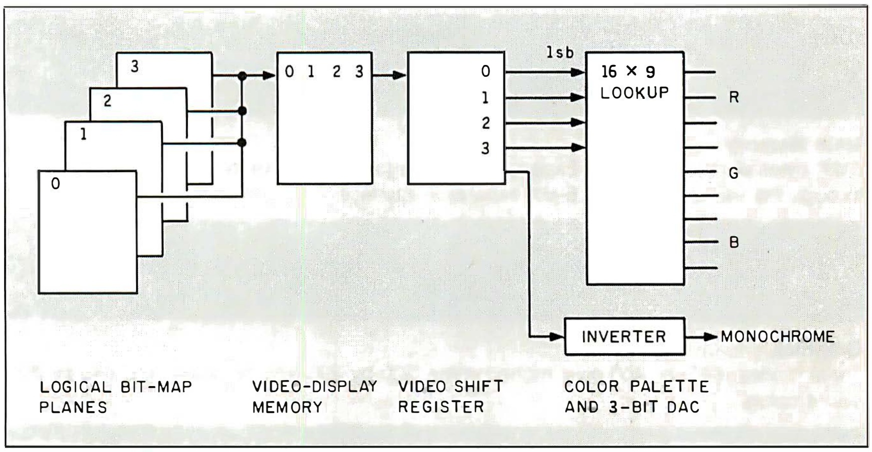


Figure 4: *The flow of data from video memory to analog* RGB *output.*

GLUE

The Glue chip reduces the overall chip count on the board by integrating the functions of many smaller chips into one device. Glue generates chip selects, handles handshaking (for parts that aren't 68000-bus-oriented), and generates both the video timing and the interrupt controls. Although the 68901 handles part of the interrupt management task, Glue takes the interrupt from the 68901 and determines its priority with respect to the vertical and horizontal interrupts. Glue also handles the actual interrupt acknowledge cycles.

I/O CHIP

The 68901 MFP (multifunction peripheral) chip is a standard member of the 68000 family and provides serial I/O, parallel I/O, timers, and counters. It has eight parallel I/O pins; a 16-source interrupt controller with programmable service modes, including polling and vector generation; four separate timers with individually programmable prescaling; and a single-channel, full-duplex USART (universal synchronous/asynchronous receiver/transmitter).

SOUND

The Yamaha YM2149 sound chip has three independent monophonic voices and uses a 2-MHz clock input

(continued)

IN BRIEF

Name
Atari 520ST

Company
Atari Corp.
1196 Borregas Ave.
Sunnyvale, CA 94086
(408) 745-2000

Price

Monochrome system	$799
Color system	$999

Microprocessor
Motorola 68000, a 32-/16-bit microprocessor (32-bit internal architecture with 24-bit, nonsegmented, external data bus) running at 8 MHz

Main Memory
512K bytes of dynamic RAM. Expansion to 4 megabytes may be possible in the future through the use of a planned 8-slot expansion interface.

ROM
Current models contain 16K bytes of boot-up ROM. Atari intends to release TOS on ROM for $20, upgrading ROM to 192K bytes and freeing up that amount of RAM.

Graphics
Three modes: 640- by 400-pixel monochrome, 320 by 200 with 16 colors, and 640 by 200 with 4 colors

Sound
Three independent sound channels from 30 Hz to 125 kHz

Floppy-Disk Drive
Bundled, external 3½-inch single-sided double-density drive with capacity of 360K bytes. System supports maximum of two floppy-disk drives.

Keyboard
94-key Selectric-style QWERTY keyboard with numeric keypad, cursor controls, and rhomboid function keys

Interfaces
MIDI in and MIDI out ports
Monitor port (supports RGB analog, high-resolution monochrome)
Centronics parallel printer port (supports Epson-compatible printers)
RS-232C serial port
Floppy-disk port
Hard-disk port (10-megabit-per-second DMA transfer rate)
128K-byte ROM cartridge port
Ports for mouse or two joysticks

Bundled Software
TOS, including GEM
Atari Logo
BASIC, when completed

Optional Peripherals/Expansion

SF354 single-sided drive	$199
SF314 double-sided drive	$299
1-megabyte RAM upgrade (Lemon Micro, Redondo Beach, CA)	$300

Planned Peripherals
SMM801 dot-matrix printer, SDM121 daisy-wheel printer, 10-megabyte fixed disk, RAM disk for cartridge port, 8-slot expansion interface, local-area network for MIDI port, CD-ROM

to produce tones from 30 Hz up to 125 kHz—more than the human audio range. The chip also has a noise channel. Atari documentation calls this chip the PSG (Programmable Sound Generator). The three channels of output are mixed, converted by a built-in digital-to-analog converter, and sent to a monitor speaker. The designers were also able to use some ports and registers on the PSG for activities completely unrelated to sound generation, such as controlling parts of the parallel and serial ports.

The registers for the voices control a basic square wave while the Noise Generator register controls a frequency-modulated square wave of pseudorandom pulse width. You can mix tones and noise over individual channels by using the Mixer Control register. Amplitude registers allow you to choose fixed or variable (Envelope-register-determined) amplitude.

DMA PORT

The 520ST ports fill the entire back and sides of the keyboard unit (see photo 4). One of the strongest features of the 520ST is the built-in DMA port. Using a CPU to move large blocks of data between memory and external devices is neither fast nor efficient. DMA was created to provide a speedy channel for such transfers and to leave the CPU free to calculate. Without help from the CPU, the Atari's DMA port can move data at 10 megabits per second, a rate twice the standard hard-disk transfer rate and much higher, for example, than the Macintosh, which must make do with a much slower serial port. In addition, the port can handle up to eight daisy-chained devices and is the opening to practical use of CD-ROMs and many other devices.

DMA CONTROLLER

The Memory Controller and Glue custom chips contain parts of the DMA function, but it is the DMA custom chip that directs the high-speed data transfer through the DMA port. The DMA controller and the CPU have equal access to the bus: A

(continued)

first-come, first-served scheme handles contention. Only one DMA operation can take place at a time. A DMA operation depends on the base address, the count, and the read/write status values the program loads into the DMA Base Address and Counter register. In addition, two bits are used as address lines to steer the output of the DMA to the floppy-disk port or to the hard-disk port.

DMA occurs in bursts, with the DMA chip storing information in its 32-byte FIFO (first-in/first-out) buffer and then sending it in a hurry to either RAM or to the outside world. The DMA chip and the 68000 CPU have equal access to RAM and compete for the same cycles. The DMA chip's 10-megabit-per-second rate is equivalent to 1.25 megabytes per second or 625K words per second. (The transfers to and from memory in the 520ST are handled in 16-bit words.) The 68000 can access memory every 500 ns. That means its maximum bus use is 2,000,000 words per second. A worst-case calculation (dividing the 625K words/second rate by the 2,000,000 words/second rate) shows that DMA cannot use more than 33 percent of the CPU bus cycles.

A more realistic calculation assumes a 5-megabit-per-second rate for DMA (the standard rate for hard-disk drives) and does not assume that the highest-speed bursts of DMA would run continuously, or that the CPU would reach for memory in every cycle. With these assumptions, the DMA would rarely borrow even 5 percent of the 68000's RAM access cycles.

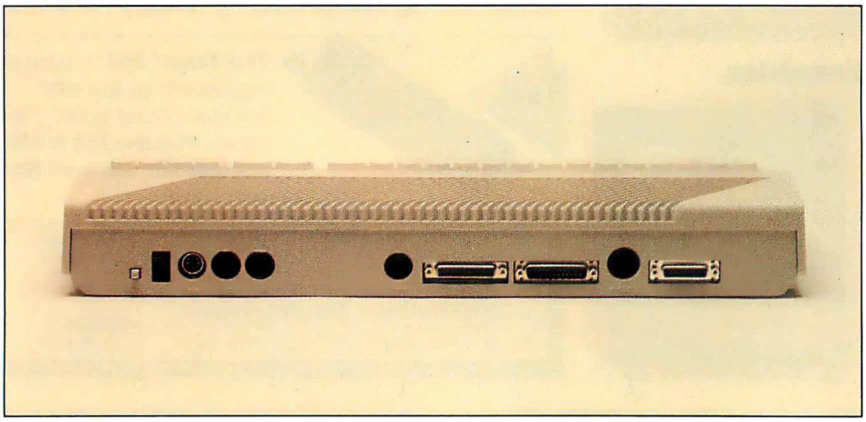


Photo 4: *The back panel of the 520ST. From left to right are a reset button, the on/off switch, power cable, MIDI out and MIDI in, the monitor port, 25-pin Centronics parallel printer port, an RS-232C serial port, the floppy-disk port, and the hard-disk (DMA) port. Out of view, on the sides, are the joystick/mouse ports and the 128K-byte ROM cartridge port. Unfortunately for left-handed users, the attachment cables for the disk drives and for the mouse are short. All but the most inventive users will place the drives on the left and the mouse on the right.*



Photo 5: *The 520ST keyboard. Wider keytops and the rhomboid shape of the function keys lessen the utility of an otherwise full-featured, well-designed layout.*

PORTS

The serial port is a standard RS-232C interface. Some of its signals come from I/O port A of the sound chip, while others are routed through the 68901 chip. The serial port can work with asynchronous data-transfer rates from 50 to 19,200 bps.

The parallel port supports the strobe and busy signals of the Centronics parallel interface standard. Both I/O port B of the sound chip and the 68901 chip help control these lines and the eight read/write data bits. The parallel lines of the sound chip are bidirectional, which could lead to some interesting hacking. For example, you might convert a parallel printer into a scanning device to digitize information. The typical data-transfer rate is 4000 bytes per second.

The two MIDI (musical instrument digital interface) ports bear special attention. MIDI is an industry-standard interface for computers and musical peripherals. The MIDI ports will allow the 520ST to attach directly to external keyboards, synthesizers, and other equipment. Atari has even been investigating the possible use of the MIDI ports for inexpensive networking of 520STs. The interfaces work at 31,250 bps for serial transfer of information from the keyboard or a program to and from external devices. Data is organized as a start bit, eight data bits, and one stop bit.

One of the 6850 chips controls the MIDI serial communication. Up to 16 channels are allowed on the MIDI bus in one of three network addressing

(continued)

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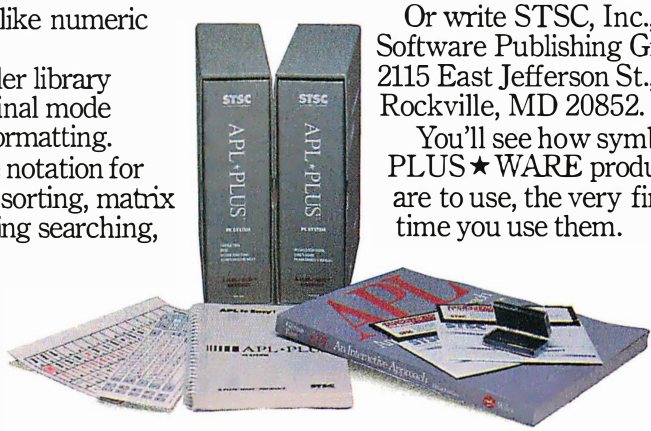
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modes. The Omni mode addresses all units simultaneously and is the default mode when the computer is first turned on. Poly mode addresses each unit separately. Mono mode addresses each unit voice separately.

KEYBOARD AND MOUSE

The documentation refers to the 94-key keyboard (see photo 5) as the Atari Intelligent Keyboard because it uses its own 1-MHz 6301 microprocessor with its own mask-programmed ROM. The device scans the keyboard and the joystick/mouse ports. It provides two-key rollover and sends keyboard, mouse, trackball, joystick, and time-of-day information to one of the 6850 ACIA (asynchronous communications interface adapter) chips on the main computer board. The lines are bidirectional, and the 6850 also sends commands to the keyboard.

The QWERTY keyboard has a standard Selectric-style layout with 10 rhomboid function keys, a numeric keypad, and four cursor-control keys. Many applications for the 520ST will use two special keys, Help and Undo. We found the keyboard layout pleasant in appearance and extremely functional. It closely resembles the DEC VT-100 layout. The Control and Return keys are well placed, and the Return key is a three-key-size reverse L shape and hard to miss. The shape of the function keys, however, may make it difficult to avoid hitting more than one.

More of a problem is the feel of the keyboard. Each keytop is ⅛-inch wider than the keytops on the Macintosh and IBM PC keyboards. As a result, the keys seem much more closely packed, and you may tend to press two at a time more often than usual. In addition, the keys on our unit required noticeably more pressure than do the keys on most other small systems. And, because connectors are attached to the rear of the unit, it is relatively difficult to adjust the keyboard.

The mechanical two-button mouse, which attaches to a port on the right side of the unit, has a resolution of 100 counts per inch and can handle a maximum velocity of 10 inches per second. It has a good feel. You will use the left button for most manipulations, including select and dragging within GEM. The right button is application-dependent. For example, NEO, a low-resolution paint program, uses the right button to copy images. There are keyboard alternatives to all mouse functions, though I suspect few of you will ever use them.

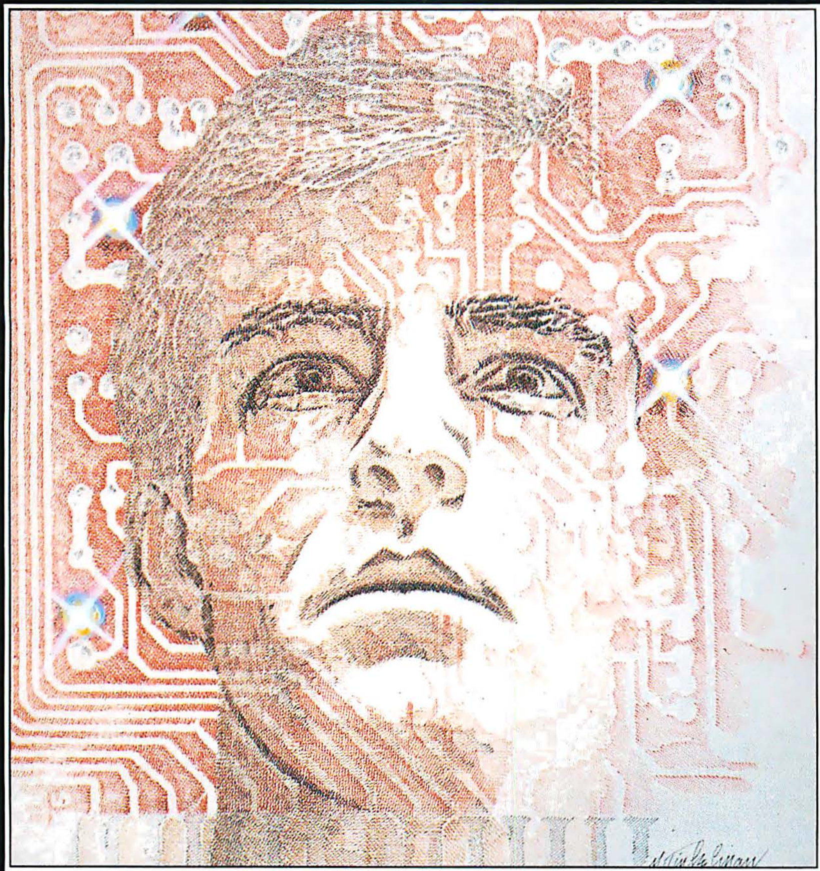
DISK DRIVES

We were impressed by the high data-transfer rate of both the floppy-disk

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drives and the hard-disk drives we tested with the 520ST. The speed is a tribute to the efficiency of the DMA custom chip and the WD1772 floppy controller. I/O is quick (no endless waiting during disk reads), and, unlike the Macintosh, you can remove disks easily at the touch of a button on the drive. The standard system currently includes one single-sided double-density drive with a capacity of 360K bytes. For $299, you can obtain a double-sided drive that can store up to 720K bytes. Setting up the drives is slightly more unforgiving than daisy-chaining on Atari's 8-bit systems in that you must use the designated in and out I/O ports on the back of the drives. Still, adding the second drive is a distinct plus. With it, you can copy an entire disk (without the four swaps required if you don't have one) in 99 seconds and copy a 32K-byte file in 16 seconds. The disk-copy operation does not automatically format the disks, which requires an additional 54 seconds for the single-sided disks.

The disk format employed is very similar (down to the file-allocation tables) to that of the MS-DOS disks used on the Data General/One portable computer. However, the formats are not absolutely identical. We took a disk from a DG/One that contained a text file and slipped it into the 520ST disk drive. The GEM desktop on the 520ST recognized the disk and showed it contained a file, but the 520ST wasn't able to open the file for printing or display. When questioned about this, Atari admitted that a utility will probably be necessary to read the files.

Floppy-Disk Controller

Atari didn't design the floppy-disk controller. The design team chose a chip with a built-in data separator, a modified version of the 1770 chip from Western Digital. The old chip worked with 6-, 12-, 20-, and 30-millisecond drives. Atari asked Western Digital to change some of the drives that they support, and the new chip—the 1772—can work with 2-, 3-, 5-, and 6-ms stepping speeds. Atari is using

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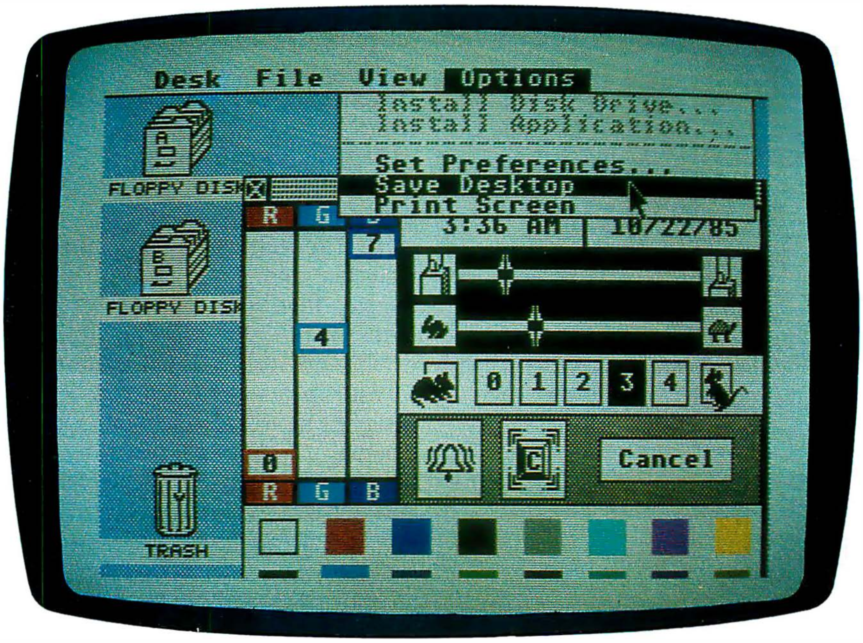


Photo 6: *The 520ST desktop in low resolution, showing the control panel and a customized background color. You can fix your choices by saving the desktop.*

3-ms drives. The chip uses the System/34 format. There is some incompatibility between the 1772 and the 765 controllers (the chip used in the IBM PC), although the format is the same.

The floppy interface will support a maximum of two daisy-chained floppy-disk drives. You send commands to the FDC (floppy-disk controller) by first writing to the DMA Mode Control register (to select the FDC internal command register) and then writing the desired 1-byte command to the Disk Controller register. The floppy controller works through the DMA controller custom chip, just as all hard-disk transfers do.

HARD DISK

Although Atari hasn't yet released its planned 3½-inch hard disk for the 520ST system, the company let us play with a 10-megabyte prototype, which transfers data at 5 megabits per second, the standard ST506 rate. Later drives will feature 15 megabytes and 7.5 megabits per second.

There is no hard-disk controller inside the 520ST. But the DMA custom chip makes for easy, fast interfacing. The AHDC (Atari hard-disk controller) will be in the hard-disk-drive unit. The DMA controller sends commands to the hard disk using the ANSI X3T9.*x* SCSI (small computer systems interface)-like command descriptor block protocol. The AHDC supports a minimal subset of SCSI commands that are sent to the AHDC in much the same way that commands are sent to the FDC. Both floppy- and hard-disk formats contain 512-byte data sectors.

MONITORS

We used both the monochrome SM124 and RGB SC1224 monitors with excellent results. The color monitor supports low and medium resolution. You can use the monochrome monitor only for high resolution. All of the displays are clear, sharp, readable, and flicker-free, but we were particularly impressed by the clarity of the high-resolution monochrome.

The monitor you connect when you boot will determine the resolutions you will have available; there is only one monitor port, and you cannot unplug one and connect the other, since they have no compatible resolution. This may give some users a difficult choice, since much of the early software will work with one monitor or another but not both. For the moment, if you are interested in buying the 520ST for business or programming uses, you would be best served with the high-resolution monochrome system. Nonetheless, developers will undoubtedly make available resolution-independent software, in part because the developer's kit includes an appropriate directive.

TOS

TOS (the 520ST's operating system), including the GEM overlay, was to be in ROM and obviously would boot very quickly. As of this writing, however, it is in RAM where, in addition to taking up over 206K bytes of RAM, it requires 32 seconds to boot. Still, this leaves you with a reasonable amount of workspace until Atari releases the ROM version. In the meantime, 16K bytes of ROM (two 64K-bit ROM chips) hold the boot-up code for the computer. Four empty sockets within the 520ST await the new ROM chips.

The appearance of the desktop depends upon the monitor and the resolution (see photos 6 through 8). It has some unusual features and some annoyances, but for the most part, those familiar with the operation of the Macintosh will feel at home. The menu bar is at the top, you can use the mouse to resize and move windows and to work scroll bars and sliders, and you can click on file icons to format disks, to get directories, and to rename or get detailed information on files and folders. Like the Macintosh, you double-click on icons to open them, drag icons to copy files and disks, or use shift-clicks for multiple file copying. Undoubtedly, the most impressive aspect of the interface is the speed with which you are able to resize and move windows.

Those expecting a clone of the Macintosh interface, however, will be disappointed. And several of the differences are annoying. It takes slightly but noticeably longer to click on the boxes within the windows, and resizing, though quicker, is somewhat

more awkward. For example, when you click on the Resize box, the new 520ST window automatically reduces in size. On the Macintosh, it stays the same size until you decide to alter it.

There are other important differences between the 520ST and Macintosh desktops. The trash can is actually an incinerator. Move a file or folder there and it's gone permanently. Unlike the Macintosh, whenever the pointer even touches the menu bar, you bring down the menus. To eliminate the menu, you have to bring the pointer off the menu and click the mouse button. It's amazing how often this happened to us by accident. The selection process would be much improved if only you had to press the button to select menus. Second, the 520ST desktop seems to have partitions into which icons can fit. Unlike the Macintosh, in which you can place icons where you wish, the icons have a finite number of possible locations. Third, there is no option to move files, folders, and applications. The only available options are copy and delete. Therefore, to move an icon into a folder you will need to copy it there and then delete the original. And, to move a file out of a folder, matters are further complicated by the fact that the folder opens to take over the window from which it derived. You would first have to move the file to a different disk, delete the original file from the folder, then copy the file back to the original disk but not within the folder, and then delete the first copy you made. It sounds difficult because it is.

From the current desktop, you have access to a VT-52 emulator, you can install your printer, you can configure the RS-232C port, and you can set any of several defaults on a control panel. For example, if you have the color system, you can alter the palette and thus affect, if you wish, the appearance of the desktop and other applications. In low resolution, you can modify all 16 colors from the palette of 512; in medium resolution, you can modify up to 4. You can also set when and at what rate the keys will repeat with the keyboard response selectors, you can alter the double-click response time, and you can activate or deactivate the keyboard click and the pleasant-sounding error warning bell. However, there are few editing amenities when resetting the time and date, a small annoyance since the 520ST has no internal battery maintaining the clock. Most of the time, you will have to type in the entire date and time string.

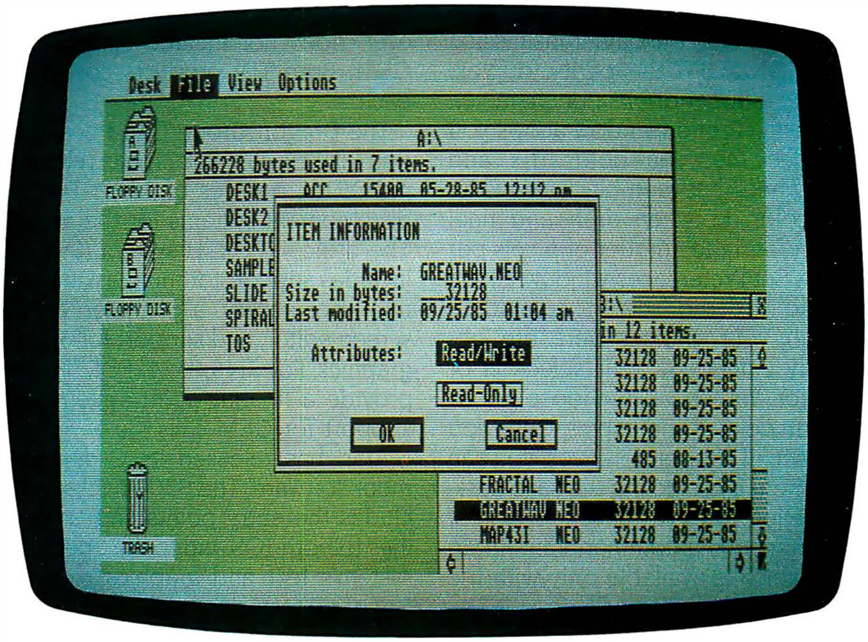


Photo 7: *The 520ST desktop in medium resolution. Icons are the default, but you can easily set your preference to text.*

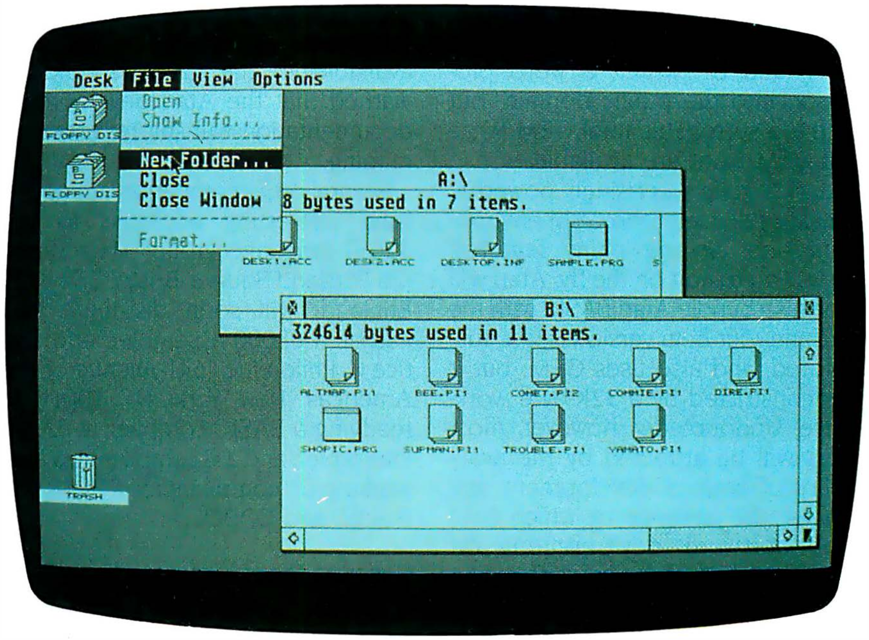


Photo 8: *The 520ST desktop in high resolution.*

(continued)

The RS232 Port Configuration window lets you fix the data-transmission rate, XON/XOFF, the parity, duplex, and the number of bits per character. The Install Printer window allows you to select between dot-matrix and daisy-wheel, between black-and-white and color, between draft and final quality, and the number of pixels per line. A Set Preferences window allows you to set the screen resolution, though your choices here are obviously limited by your selection of monitor. You can also choose not to confirm deletes and copies. Once you have set all your preferences, you can save them by selecting the save desktop option. The only absent option of importance is a command-line interface, which is available only with the 520ST developer's package.

SOFTWARE

The system comes bundled only with TOS and Atari Logo, and like other new systems, there is at present a dearth of software. Already, however, Atari has released NEO, a paint program, and ST Writer, a word processor, into the public domain, but both are surrogates until GEM Write and GEM Paint are available.

Atari Logo is surprisingly powerful. It makes full use of the GEM environment and, among many features, allows you to edit on the fly. Atari will soon also bundle Atari BASIC with the machine. Our beta version is fast, full-featured, and also uses GEM, but it was constricted by a 32K-byte workspace. Undoubtedly, however, most users will be attracted by the availability of serious development languages, the absence of which held back software development on Apple's Macintosh for most of its first year.

TDI Software Ltd. (29 Alma Vale Rd., Clifton, Bristol BS8 2HL, England) has released Modula-2/ST, a 32-bit development system that includes an editor, compiler, linker, and library facilities. TDI's Modula-2 is a full implementation, has complete libraries for TOS, and provides full access to the 520ST's graphics features. TDI is also marketing a version of UCSD Pascal with the p-System, which, however, does not include support for GEM. Both TDI products cost £195 each.

The Dragon Group (148 Poca Fork Rd., Elkview, WV 25071) has released 4xFORTH, a series of 32-bit FORTH development systems for the 520ST. The basic 4xFORTH system ($99.95) includes support for multitasking and multiuser access, a compiler, a full-screen editor, and support for 520ST graphics. For $149.95, 4xFORTH also provide a floating-point system and support for GEM calls.

Atari has released its C development software. The $300 package includes the entry points and C bindings to both TOS and to the operating system's text and graphics routines (such as text size, attributes, alignment, and angle, as well as circle drawing, area fill, and bit-blitting). The documentation also provides the "Hitchhiker's Guide to the BIOS," information on Kermit and MIDI, a C programmer's guide, and much more. Purchasers of Haba's Hippo-C, now available for the 520ST, should be warned that the Atari development documentation will still be essential reading.

Several other companies are promising interesting additions to the 520ST language group. Metacomco (26 Portland Square, Bristol BS2 8RZ, England) will soon distribute ISO Pascal, a 68000 assembler, and Lattice C. Philon Inc. (641 Avenue of the Americas, New York, NY 10011) is readying a BASIC compiler, a BASIC interpreter, and a C compiler. It is also working on compilers for FORTRAN, Pascal, and COBOL.

SYSTEM DOCUMENTATION

It is fortunate that the system is so easy to learn to use because the documentation is quite poor. The 80-page owner's manual has requisite sections on setting up the system, getting started, touring the GEM desktop, and managing disks, files and folders, but it has very little technical material. Materials with the disk drive and monitors are also sadly lacking. Undoubtedly, users will have to wait for the trickle of technical references on working with the hardware.

CONCLUSION

Judging from the conversations around the office and on BIX (BYTE Information Exchange), CompuServe, and The Source, there is a storm of interest in comparing the relative capabilities of the 520ST, the Amiga, and the Macintosh. There is, in fact, far more interest than there seemed to be in comparing the merits of the 8-bit computers from Atari, Apple, and Commodore. An upcoming special edition of BYTE on the 68000 will make comparisons of processor and application speeds, ease of development and portability, and user interfaces, but we are still left with our conclusion that these are very different machines, with very different markets.

The 520ST is an architecturally simple 68000 computer with high-quality video output and a high-speed DMA port. The easiest way to summarize our first look at the hardware is that the 520ST presents the 68000 unbounded. Not only does it offer an excellent price/performance ratio, but we expect it to produce some impressive benchmarks on tasks with heavy computation.

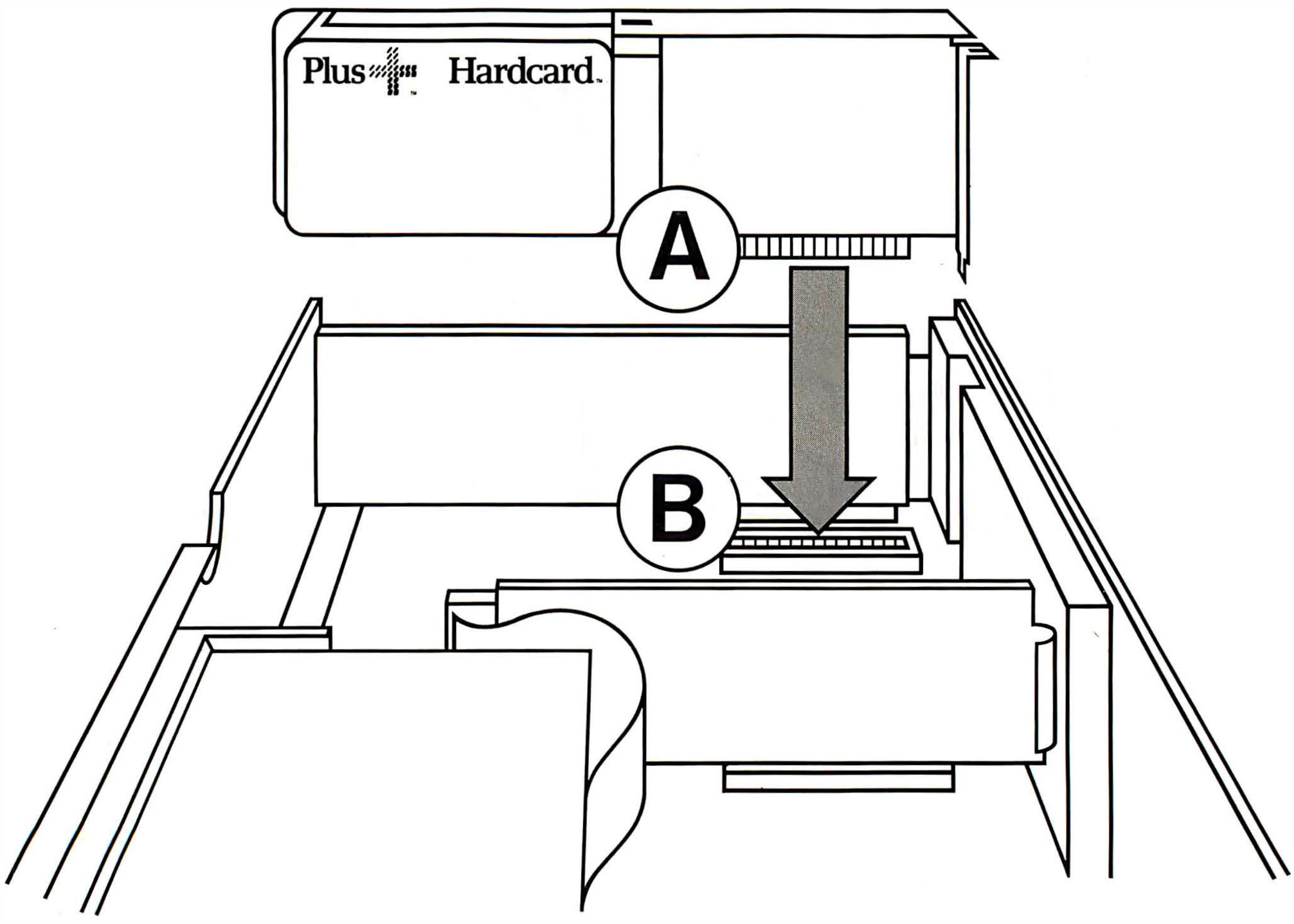
The 520ST's complete keyboard and impressive array of ports add up to an attractive system. Finally, the 520ST's use of standards (for example, 68000, MIDI, Yamaha sound chip, and Western Digital FDC) should make it easier to program, expand, and manufacture.

There are also the promised cheap, powerful peripherals: a 10-megabyte hard disk for $700, a ½-gigabyte CD-ROM optical disk for around $500, and a 1200-bps modem for $150.

The Atari 520ST is certainly an excellent value. For the moment, there is not much application software and you still have to deal with an unfinished operating system; but with the current availability of several high-level languages, the 520ST will undoubtedly provide many users with what they seek—a means to tap the power of the 68000 at a price they can afford. ■

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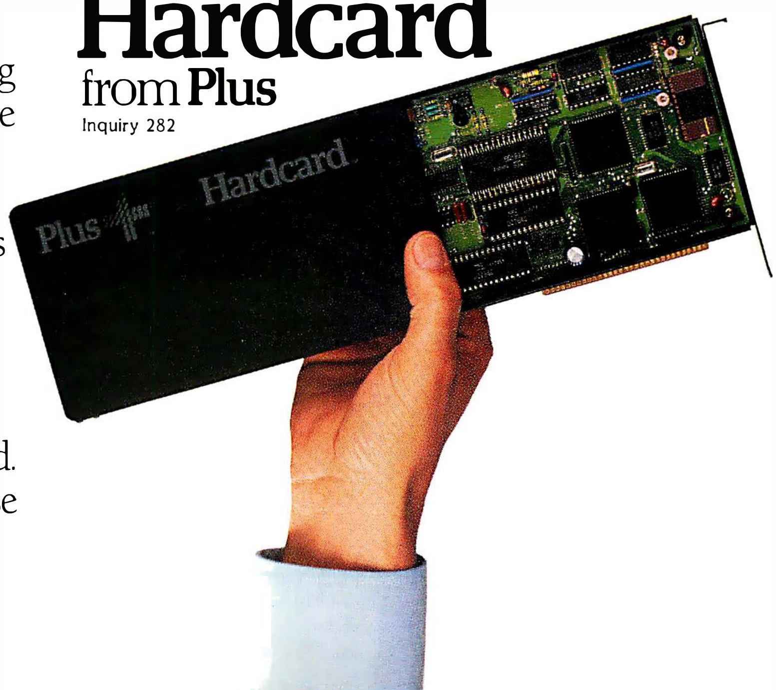
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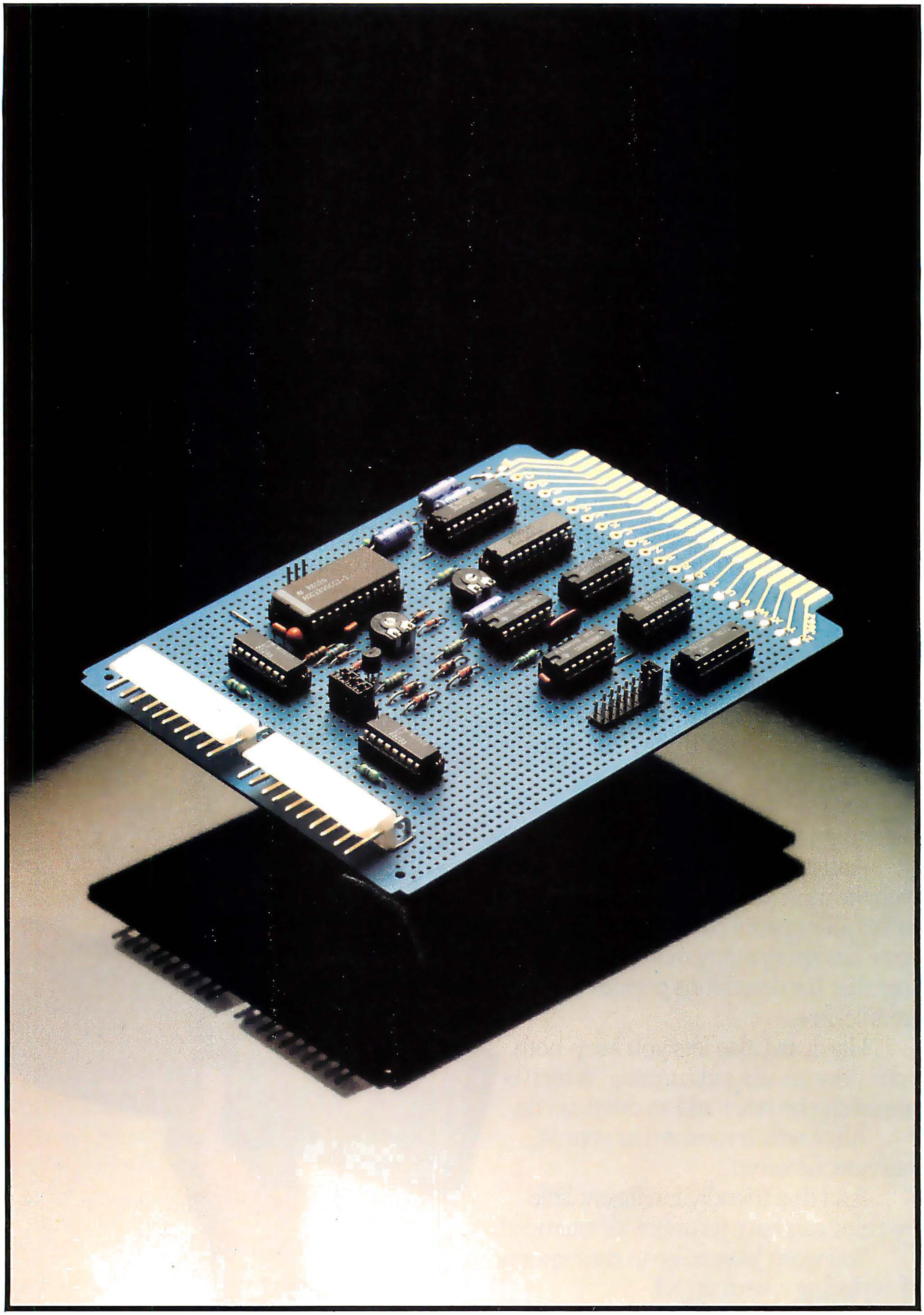
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PHOTOGRAPHED BY PAUL AVIS

BUILD AN ANALOG-TO-DIGITAL CONVERTER

BY STEVE CIARCIA

A 16-channel 12-bit high-speed A/D converter

It is evident that many applications for computer controls, including energy management, security, and environmental monitoring, require measurement inputs and control outputs in quantities not easily expressed in the 0- and +5-volt TTL (transistor-transistor logic) levels present in your computer.

An energy-management system, for example, may need to monitor a temperature range of 0 to 100° C with a resolution of 0.1 degree. The thermocouple sensing this temperature range might generate only 1 or 2 millivolts per degree. A proportional-drive pump motor in the same system might require a 2.40-V set-point control input to produce the proper flow rate throughout the system.

Continuous analog systems like these are in the real world, outside the binary logic-0 and logic-1 domain of digital computers. For the computer to interact with the real world, we need some scheme for translating analog measurements to and from quantized binary equivalents.

This is not the first time I have touched upon analog-to-digital and digital-to-analog conversion. I try to cover this topic every three or four years so that new readers can be brought up to speed on the basics. For the old-timers, however, I spice up the project with the latest whiz-bang conversion interface that can be cost-effectively produced.

The previous projects have all used 8-bit converters. However, the overwhelming response to the BASIC-52 computer/controller (BCC-52) presented in the August 1985 Circuit Cellar has created a demand for something more challenging. Thousands of BCC-52 industrial and end users are applying computer control to applications that ultimately require greater accuracy of measurement.

Presently, an 8-channel 8-bit A/D converter (10,000 samples per second, 0 to 10 V or −5 to +5 V, P/N BCC-13) is available for the BCC-52, but many measurements require more resolution. Therefore, it's time to dust off the old theoretical explanations and present an up-to-date, high-speed, high-resolution A/D interface for the BCC-52.

First, because one is an integral component of the other, I'll outline the basics of D/A conversion and then go on to A/D conversion. After a few circuit examples, I'll get

(continued)

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into the heavy stuff. Ultimately, this month's project is the design of a 16-channel (8-channel differential input) 12-bit plus sign bit, −5 to +5 V, 10,000 samples/sec, BCC-52/Z8 bus-compatible A/D converter board. In a few months, after I have presented a few more essential peripheral devices, I will demonstrate the configuration and application of a full-fledged data-acquisition and control system based on the BCC-52.

D/A CONVERSION

The D/A converter can be thought of as a digitally controlled programmable potentiometer that produces an analog output voltage. This output voltage (V_o) is the product of a digital signal D, a multiplier constant K (usually 1), and an analog reference voltage V_{ref}, related by the following equation:

$$V_o = KDV_{ref}$$

The binary value transmitted to the D/A converter by the computer is a binary fraction representing what portion of the full output voltage is emitted. The fraction is multiplied by a reference voltage, which can be either fixed or variable. D/A converters with variable reference voltages are often referred to as multiplying D/A converters, although all D/A converters can be said to multiply.

In finite binary fractions, the most significant bit (MSB) has a value of 1/2 (that is, 2^{-1}), the next most significant bit is 1/4 or 2^{-2}, and the least significant bit (LSB) is $(1/2)^n$ or 2^{-n}, where n is the number of bits in the binary fraction. If all the bits in the fraction are added, the sum approaches 1; the more bits in the fraction, the closer the sum is to 1. The difference between 1 and the approach to 1 is the quantitation error of the digital system. I'll discuss this later.

Different implementations of D/A and A/D converters use different formats for representing the binary digital quantities. One basic difference is how systems represent negative binary numbers and negative voltages; some can, and some can't. Analog interface systems that can manipulate positive and negative numbers and voltages are called bipolar converters; systems that can handle only positive voltages and quantities are called unipolar.

Unipolar converters chiefly use straight binary and binary-coded-decimal (BCD) representations of digital quantities. Bipolar converters use a variety of representations, including offset binary, one's- and two's-complement formats, and Gray code. For brevity, I will limit this discussion to converters using straight-binary and offset-binary representations. Later, I will get into two's-complement representations since the converter chip used in this project represents

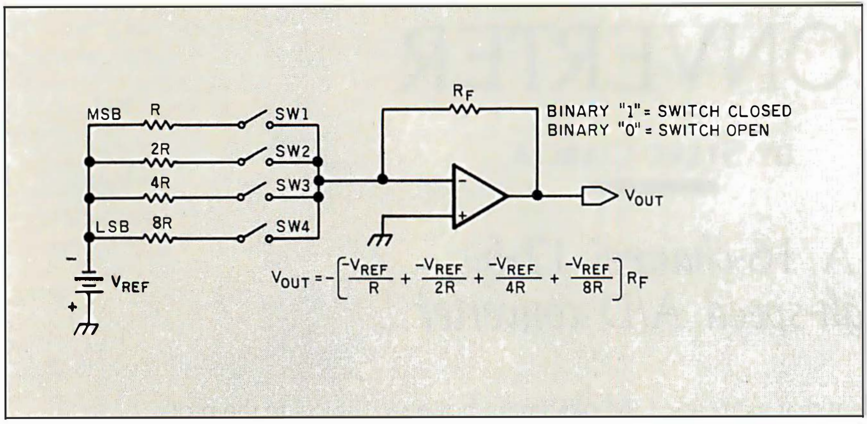


Figure 1: *A 4-bit weighted-resistor D/A converter. A 4-bit word is used to control four single-pole single-throw solid-state switches. Each switch is in series with a resistor. The resistor values are related as powers of 2. The other sides of the switches are connected together at the summing point of an op amp. Currents with magnitudes inversely proportional to the resistors are generated when the switches are closed. They are summed by the op amp and converted to a corresponding voltage.*

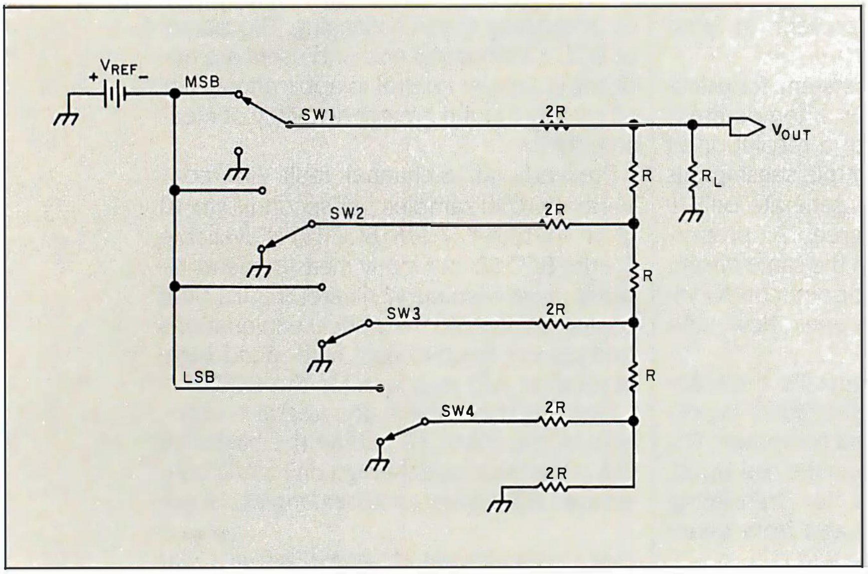


Figure 2: *A 4-bit R-2R-type resistor-ladder D/A converter. The topology of this network is such that the current flowing into any branch of a three-branch node will divide itself equally through the two remaining branches. Because of this, the current will divide itself in half as it passes through each node on its way to the end of the ladder.*

negative numbers in two's-complement form.

Offset binary differs from straight binary only slightly. In offset binary, a number consisting of all zeros represents the most negative possible quantity. The most obvious consequence of this is that the MSB acts as a sign bit, 0 for negative values and 1 for positive. For instance, in offset notation, the bit string 01000000 represents −64, while the bit string 11000000 stands for +64.

Frequently, offset notation is referred to as a resolution value plus sign bit, i.e., 12-bit plus sign converter. The sign bit, while performing as a thirteenth bit in bipolar operation, should not be confused with a 13-bit converter. The sign bit can be used to indicate only quantities above 0 V (in this case, sign bit=0) or below 0 V (sign bit=1) and not shifted in scale. Between −5 V and +5 V on a 12-bit plus sign converter, there will be 8192 divisions (13 bits). However, if the converter were to measure inputs only in the range of 0 to 5 V, only 4096 divisions (12 bits) can be represented. In this project, the A/D is set for −5 to +5 V and is therefore indistinguishable from a 13-bit converter between these limits and would be 1 bit better than a straight 12-bit converter used to measure the same range.

The translation of digital values to proportional analog values is performed by either of two basic D/A-conversion circuits: the weighted-resistor circuit or the R-2R circuit. The weighted-resistor converter is by far the simpler and more straightforward. This parallel decoder requires only one resistor per input bit.

In the weighted-resistor D/A converter, solid-state switches are driven directly from the signals that represent the digital number *D*. Individual currents with voltage magnitudes related by powers of 2 (magnitudes of 1/2, 1/4, 1/8, . . . , 2^{-n}) are generated and summed by connecting a network of resistors with values of R, 2R, 4R, . . . , 2^nR between the reference voltage $-V_{ref}$ and the summing point of an operational amplifier (op amp) by means of the set of electronic switches. After being summed, the various currents are converted to a voltage by the op amp, as shown in figure 1.

While this may appear to be a simple answer to an otherwise complex problem, this method has some significant drawbacks. The accuracy of this type of converter is a function of the combined accuracies of the resistors, switches (all switches have some resistance), and the op amp. In D/A-conversion systems of greater than 10 bits resolution, the values of the resistors become extremely large, and the resultant current flow is reduced to such a low value as to be lost in circuit noise.

For example, in an 8-bit D/A converter with R (the value of the resistor for the MSB) set to 10 kilohms, the value of the resistor for the LSB turns out to be 1.28 megohms. With a reference voltage of 10.00 V, only 7.8 microamperes would flow into the op amp. This current is significantly below the response threshold of most low-cost op amps and would not be detected. Lowering the value of R to 100 ohms creates the opposite problem. At a reference voltage of 10.00 V, the input current to the op amp would be 100 milliamperes, more than most op amps can handle.

A reasonable alternative to the weighted-resistor D/A converter is the R-2R D/A converter, often referred to as a resistor-ladder converter. This type is more widely used, even though it uses more components than the weighted-resistor type. A simple R-2R design is shown in figure 2, including the reference voltage, a set of binary switches, and an output amplifier. The basis of this converter is a ladder network constructed with resistors of two values: R and 2R.

In each bit position of the network, one resistor (2R) is in series with the bit switch, and the other (R) is in the summing line, so that the combination forms a pi network. This suggests that the impedances of the three branches of any node are equal, and that a current *i*, flowing into a node

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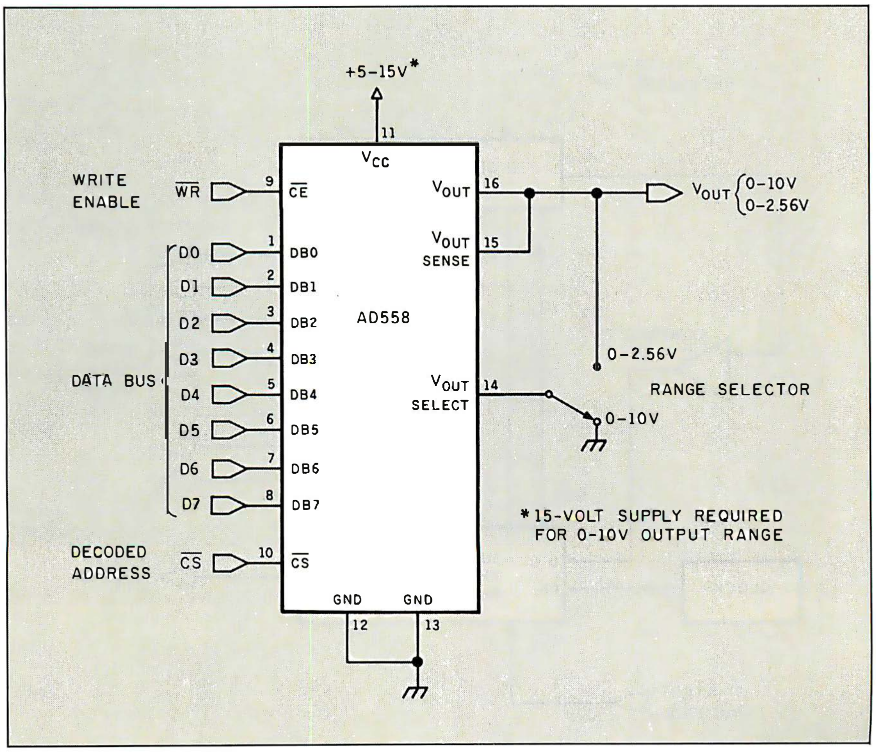


Figure 3: A *block diagram outlining a typical connection of the* AD558 *8-bit multiplying* D/A *converter.*

through one branch, flows out as $i/2$ through the other two branches. In other words, the current produced in the network by closing a bit switch is cut by half as it passes through each node on the way to the end of the ladder. Simply stated, the position of a switch with respect to the point where the current is measured determines the binary significance of the particular switch closure.

The R-2R D/A converter is easy to manufacture because only two resistor values are needed. The component stock can be reduced to one resistor value if two are used in series for each bit. Keeping matched resistor values that have the same temperature coefficients contributes to a stable design. Certain trade-offs are required between ladder resistance values and current flow to balance accuracy and noise.

One form of the R-2R ladder circuit is found in the multiplying D/A converter. This type of converter, which utilizes external-variable analog reference voltages, produces outputs that are directly proportional to the value of the digital input multiplied by this reference. Functionally, this type of converter is available as current- or voltage-output types. The current-output devices are faster and less complex because they do not include additional output-amplifier stages. Therefore, they cost less than voltage types.

An economical 8-bit multiplying D/A converter is the Analog Devices AD558. Shown in figure 3, it contains an 8-bit latch, R-2R ladder network, reference-voltage source, and output amplifier. The AD558 can run on a +5- to +15-V power supply and can be jumper-selected for 0- to 2.56-V or 0- to +10-V ranges. Using a separate op amp, you can configure an offset converter or modify the output of the range.

The AD558 can be used as a transparent D/A converter by holding the chip-enable and chip-select lines constantly low. However, it was primarily designed to be bus-operated and appear as a write-only location in memory or I/O (input/output) address space. Typical connections consist of a decoded address strobe, a write-enable signal, and the 8-bit data bus.

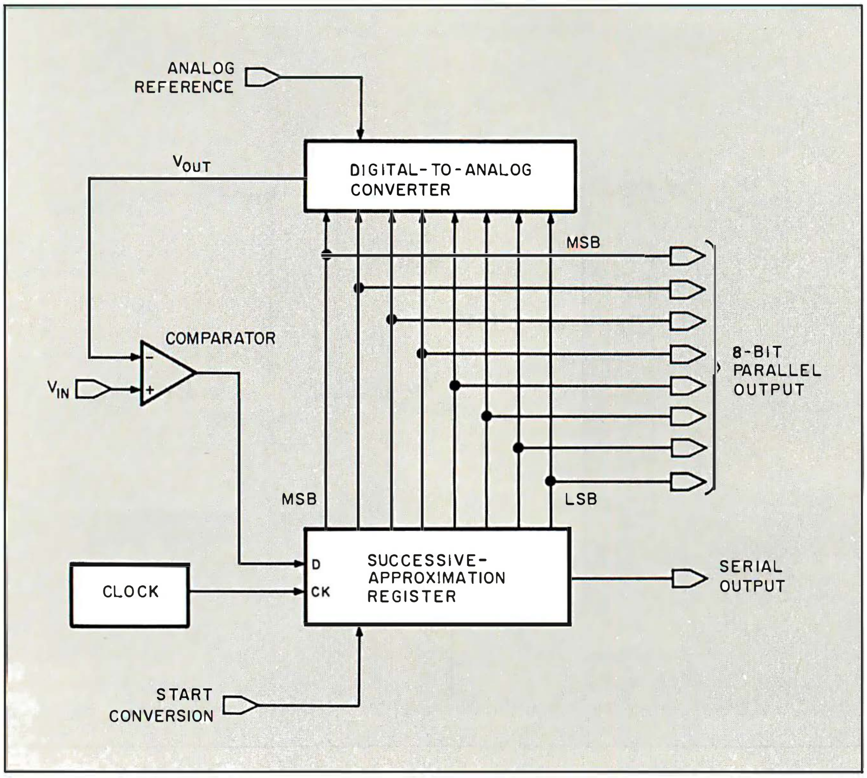


Figure 4: *A block diagram of a typical 8-bit successive-approximation A/D converter.*

A/D CONVERTERS

Virtually all high-resolution A/D converters incorporate a D/A converter as an integral component. That is why, even though our ultimate aim is A/D, I always discuss D/A converters first. Hopefully I have made you aware of the binary-conversion process, and you can appreciate the concepts of resolution and accuracy.

An A/D converter changes an analog voltage into a digital representation compatible with the computer's input needs. Akin to the 8-bit D/A converter, an A/D converter is subject to the same conversion rules. If you are trying to read a 10-V signal with an 8-bit converter, resolution is 1/256 of 10 V (approximately 40 mV), and accuracy will be ± 1/2 the LSB.

For greater resolution, more conversion bits are necessary. The number of bits does not set the input-voltage range of a converter; it only determines with what precision the output value is represented. An 8-bit converter (either A/D or D/A) can be set up just as easily to cover a range of 0 to +1 V as it can be to cover 0 to +1000 V. Often, the same circuitry is used with only a final amplification stage or resistor-divider network changed.

Note, however, that an 8-bit converter with a range of 1000 V has a resolution of only 4 V (1000/256), and it would be useless to measure 0- to 10-V signals. You can solve this problem in a number of ways. The easiest solution is to use a converter with more bits. A 16-bit converter, which has 65,536 steps instead of 256, would cover the same 1000-V range in 15-mV increments.

As a practical matter, though, a reasonable price/performance ratio is often more important than wide-range capability. A/D conversion is considerably more expensive than D/A conversion, and price is directly related to resolution and accuracy. If you intend to read 0- to 5-V input

signals and you have to be accurate within only 35 mV, it hardly makes sense to use a 1000-V range 16-bit converter (probably costing $5000) when an 8-bit 0- to 5-V range unit ($150) would more than suffice.

The rule in choosing an A/D converter boils down to "be realistic." Assess the quality of the signal source (noise, rate of change of input, ground referenced or differential, etc.) when you choose your converter. Installing a converter with 1-microvolt (μV) resolution to measure an input signal buried in 200 mV of noise is pointless.

An A/D converter that scans thermistor probes and controls the ambient temperature in a large supermarket cannot encode video information from an optical scanner. A/D converters, much more than D/A converters, are specifically tailored to an application. Speed, accuracy, and resolution are variables in any converter design, but the blending of these choices can greatly affect the cost in A/D conversion.

Most confusing is the variety of A/D-converter designs. They range from very slow, inexpensive techniques to ultrafast, expensive ones. You get what you pay for. The two fastest techniques are flash conversion and successive approximation.

The flash converter is just that. It consists of a separate analog-input comparator for each incremental voltage it is to measure. An 8-bit flash A/D converter has 256 comparators with gating logic that outputs the binary code corresponding to the comparator triggered by the input voltage. Flash converters are very fast (1 million–100 million samples/sec), but they are also very expensive.

A somewhat slower (1000–1 million samples/sec) and more cost-effective alternative is the successive-approximation converter. Shown in figure 4, this type—like the binary-ramp-type A/D converter—uses a D/A converter in the feedback loop to compare a calculated D/A voltage to the unknown input voltage. In this implementation, the binary counters are replaced with a special successive-approximation register (SAR).

Initially, the outputs of the SAR and the mutually connected D/A converter are at a zero level. After a start-conversion pulse is received, the SAR enables its bits one at a time starting with the MSB. As each bit is enabled, the comparator gives an output signi-

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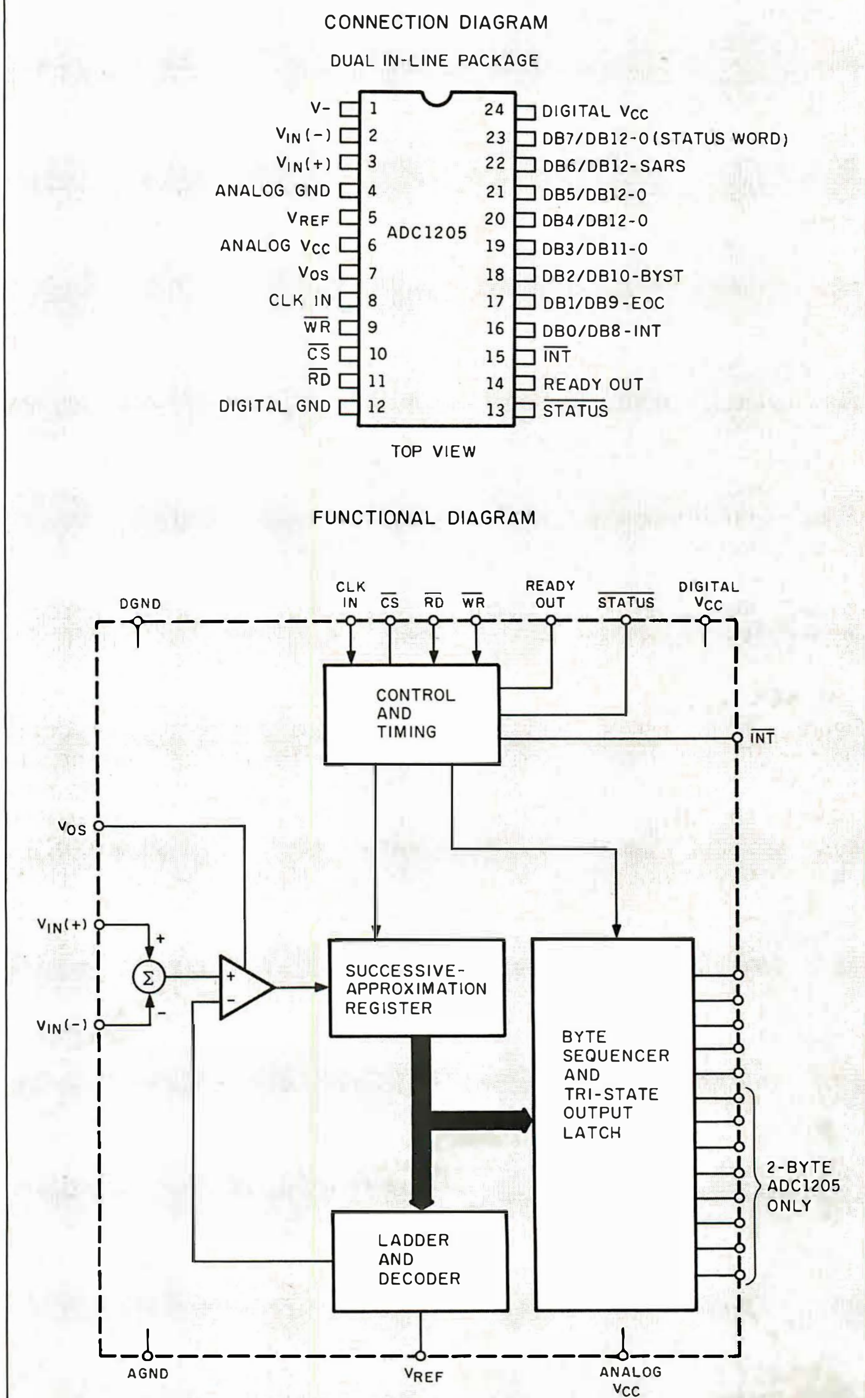


Figure 5: *Pin-out and block diagram of National Semiconductor's ADC1205CCJ 12-bit plus sign A/D converter chip.*

fying that the input signal is greater or less in amplitude than the output of the D/A converter. If the D/A output is greater than the input signal, a 0 is set as the value of the corresponding output bit. If the D/A output is less than the input signal, the circuit sets the corresponding bit to a 1. The register successively moves to the next bit (retaining the settings on the previously tested bits) and performs the same test. After all the bits have been tested, the conversion cycle is complete. An 8-bit successive-approximation A/D converter takes only eight clock cycles to complete a conversion.

This one-to-one relationship between conversion resolution and SAR clock counts is generally true only for discrete-component SAR-based A/Ds. In higher-resolution integrated-circuit A/D converters, the clock cycle/conversion bit times are less distinct due to extensive housekeeping circuitry. Like many microprocessors with high clock-crystal frequencies, the actual system clock is much slower.

THE ADC1205

Figure 5 is the pin-out and block diagram of the National Semiconductor ADC1205CCJ 12-bit plus sign A/D converter chip. It operates on a single +5-V logic supply and 5.000-V reference input to provide a 12-bit conversion on 0- to 5-V inputs. With a 1.08-megahertz clock frequency, the ADC1205 will do 10,000 conversions per second (108 microseconds per conversion).

If an additional −5- to −15-V supply is connected to V− (pin 1), the ADC1205 will convert −5- to +5-V inputs using a thirteenth output bit. This MSB is the sign bit. It is a logic 0 for positive values and logic 1 for negative values.

Figure 6 shows the output characteristics of the converter. For 0- to 5-V inputs (sign bit=0), the codes range from binary 0000000000000 to 0111111111111, respectively. In a 5-V range, each bit represents 0.0012 V, or 1.2 mV resolution! If the output of the converter were binary 0000010111100 (hexadecimal 000BC), this would be (188)*(0.0012)=0.2256 V. Similarly, binary 0110101111000 (hexadecimal 00D78) is +4.1376 V.

Negative inputs are represented in two's-complement binary. For 0- to −5-V inputs (sign bit=1), the codes range from binary 1111111111111 to 1000000000000, respectively. The output code for negative values is represented as the magnitude of the difference from the unknown input to −5 V and not its distance from zero. An output code of 1000010111100 (100BC) is −((5.00)−(188)*(0.0012))= −4.7744 V. Similarly, 1110101111000 (10D78) is −((5.00)−(3448)*(0.0012))= −0.8624 V.

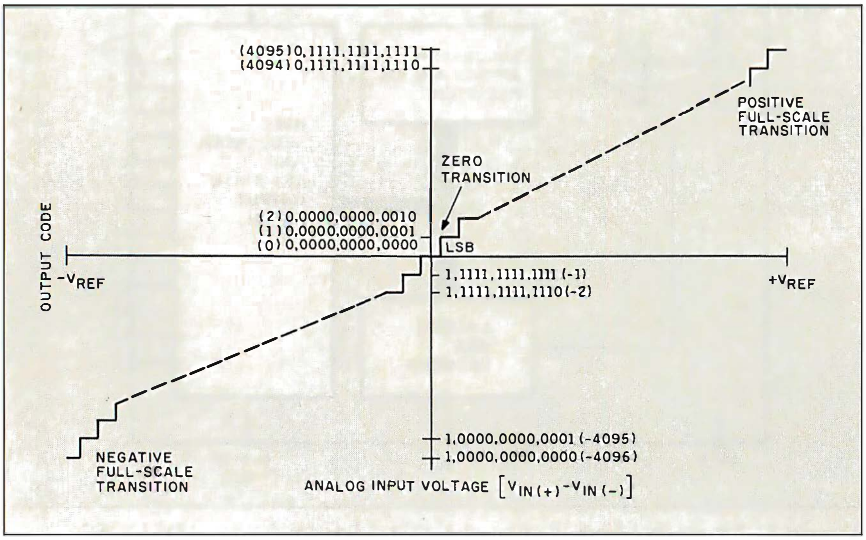


Figure 6: ADC1205 *output characteristics.*

Under computer control, the conversion is relatively easy. At each reading, determine the absolute value of the 12-bit number by multiplying it by 0.0012 V. If the sign bit is a 0, add a plus sign to your calculation, and you have a positive output of that magnitude. If, on the other hand, the sign bit is a 1, subtract that value from 5.0 V and append a minus sign. You can see that watching the sign bit is important, and this is not as simple as offset binary.

One further consideration before presenting the entire schematic is the concept of single-ended and differential inputs. There is a significant difference between them. Most low-cost multichannel A/D converters have single-ended inputs.

All converters have a V_{in+} and a V_{in-} input. In a single-ended A/D converter, the V_{in-} line is connected to ground. Therefore, all measurements are referenced to a common ground. Even if an 8-channel multiplexer switches inputs to the V_{in+} line, all readings are referenced to a single ground, and voltages from two different systems cannot be monitored simultaneously unless their grounds are connected. This is often not the case, and conditions called ground loops result. Many of you no doubt remember "smoking" an early-generation oscilloscope by accidentally viewing the hot side of the AC line while referenced through the line cord to the other side (even today I still use an isolation transformer on my scopes).

Another consideration is trying to measure voltages that are not necessarily relative to ground. Perhaps resistor R_{tc} in figure 7 is a thermistor, and we wish to read the voltage drop across it to determine temperature. A single-ended A/D converter could not be connected directly across R_{tc} if both the circuit and the A/D converter have the same ground without shorting out one of the resistors. To read the thermistor, you would have to separately read the voltages at points B and C and subtract them. Further-

more, unless you manually move the probes, the only way to do it is to increase the number of channels on the A/D converter. Hence, the proliferation of multichannel single-ended A/D converters.

Unfortunately, measurements referenced to ground often contain noise and power fluctuations from other components in the circuit. It is far better in some applications to simply measure the voltage between two points in a circuit irrespective of ground. Such a measurement is termed "differential." For lack of a better example, think of this as the two probes on a digital voltmeter (DVM). If the meter is battery-operated, it is completely isolated from ground, and the two probes measure absolute potential between them. Only when the V_{in-} probe is physically connected to the circuit ground are the readings then single-ended and ground-referenced.

The ADC1205, while being powered from ground-referenced power supplies, has analog input lines that are isolated from ground. These two lines are like the two probes on the DVM. In a multichannel single-ended A/D converter, only the V_{in+} line is multiplexed. The V_{in-} line is attached to ground. In a differential-input multichannel A/D converter, both the V_{in+} and V_{in-} lines are multiplexed, and neither is tied to ground. To read across R_{tc}, the V_{in+} line is attached to point B, and the V_{in-} line is connected to point C (in industry parlance, V_{in+} is V_{in} High and V_{in-} is V_{in} Low).

The ADC1205 is a 12-bit converter designed to attach directly to an 8-bit microcomputer bus. The system communicates with the chip as memory-mapped I/O through the $\overline{CS}$ (chip-select bar) and $\overline{RD}$ (read bar) $\overline{WR}$ (write bar) signals. An additional $\overline{STATUS}$ (status bar) line is used as a signal to start conversion or check conversion progress.

The 12 bits and sign are read as 2 successive bytes. Data is right-justified with the most significant byte presented first (the 4 MSBs of the first byte all have the value of the sign bit). A second read to the chip automatically presents the least significant byte. The three possible interactions are given in table 1.

Communicating with this chip may look complicated, but it is much less so than you might think, especially if you are operating the converter in BASIC. I will demonstrate it shortly.

The BCC-30 16-Channel A/D Converter Board

When you invent things, you get to name them. I called the BASIC-52 board the BCC-52. Since this A/D converter board is BCC-bus-compatible, I've decided to call it the BCC-30 (other more appropriate numbers are unfortunately taken). See photo 1. The schematic of the BCC-30 is shown in figure 8.

The configuration of the BCC-30 is as a bus-compatible peripheral device to the BCC-52 and the BCC-11 Z8-based computer/controller redesigned from the original presentation in July 1981. See photo 2. Both units and a number of expansion boards I've designed over the years share a common 44-pin bus sometimes called

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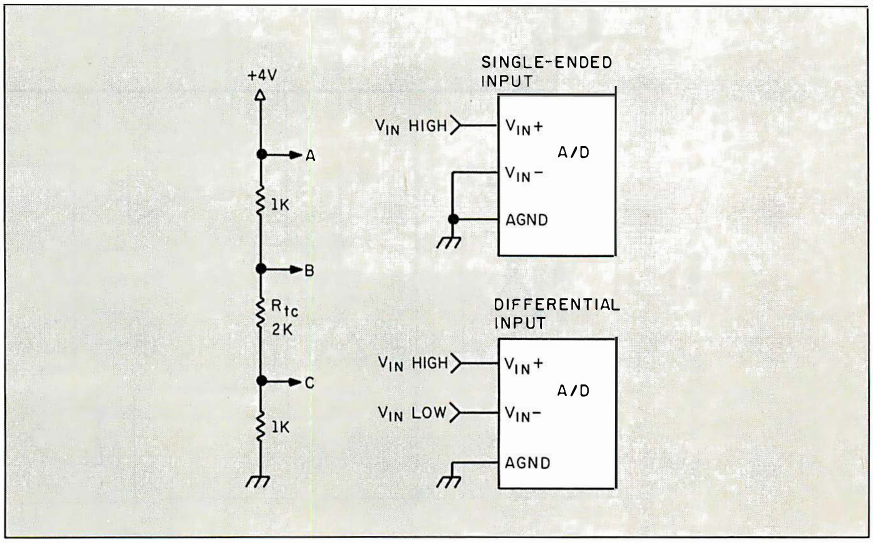


Figure 7: *Comparison of single-ended versus differential input connections.*

Table 1: *The three possible interactions with the* AC1205 A/D *converter chip.*

$\overline{CS}$	$\overline{RD}$	$\overline{WR}$	$\overline{STATUS}$	Function
0	1	1	0	Reset data-byte counter and start conversion.
0	0	1	1	Read data. First byte is sign and 4 MSBs; second byte is 8 LSBs.
0	0	1	0	Read status word.
			Status-word format:	Bit 0 — High indicates conversion complete and data ready. Bit 1 — High indicates conversion complete. Bit 2 — High indicates next byte is 8 LSBs. Low indicates next byte is sign and 4 MSBs. Bit 6 — High indicates conversion still in progress.

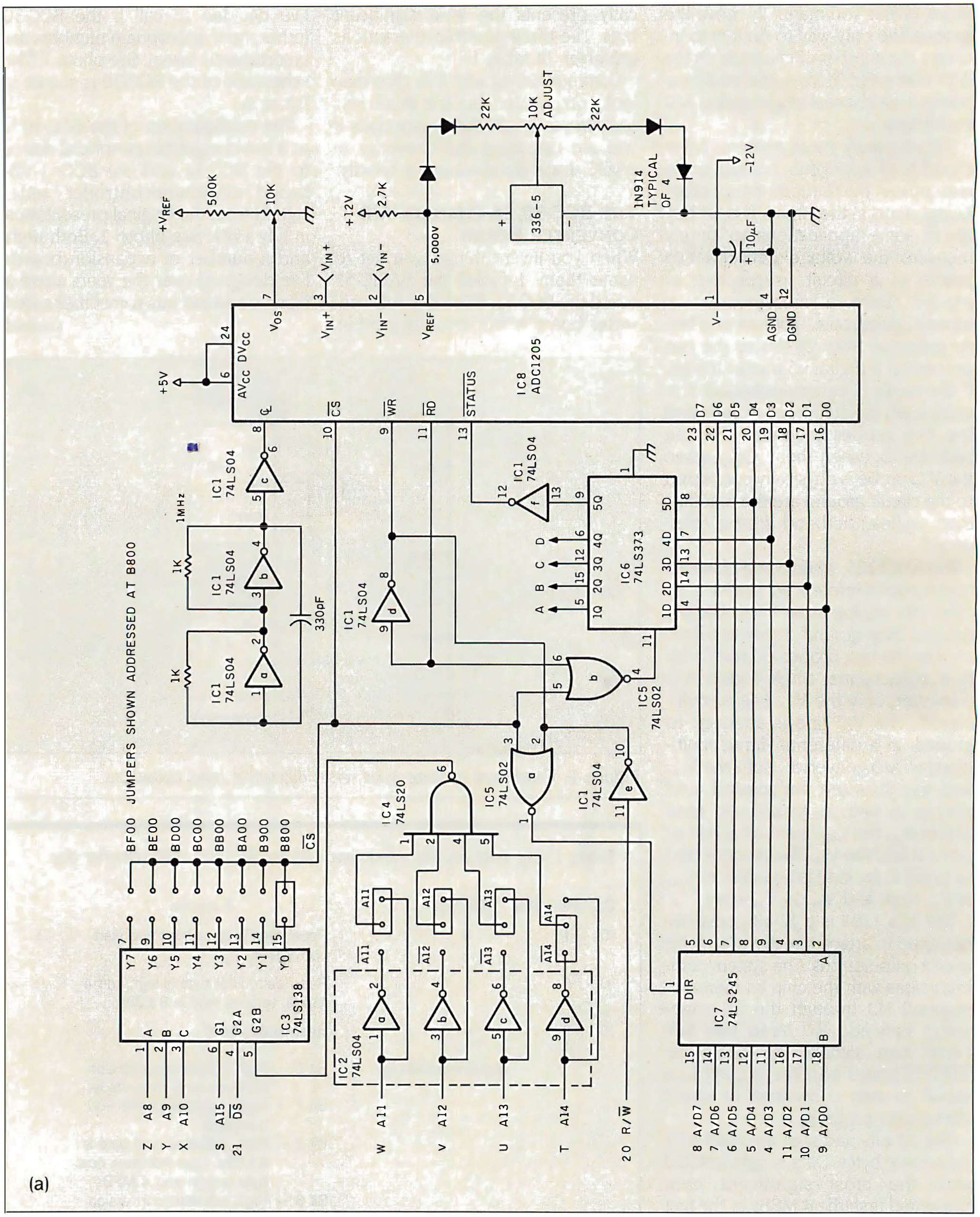
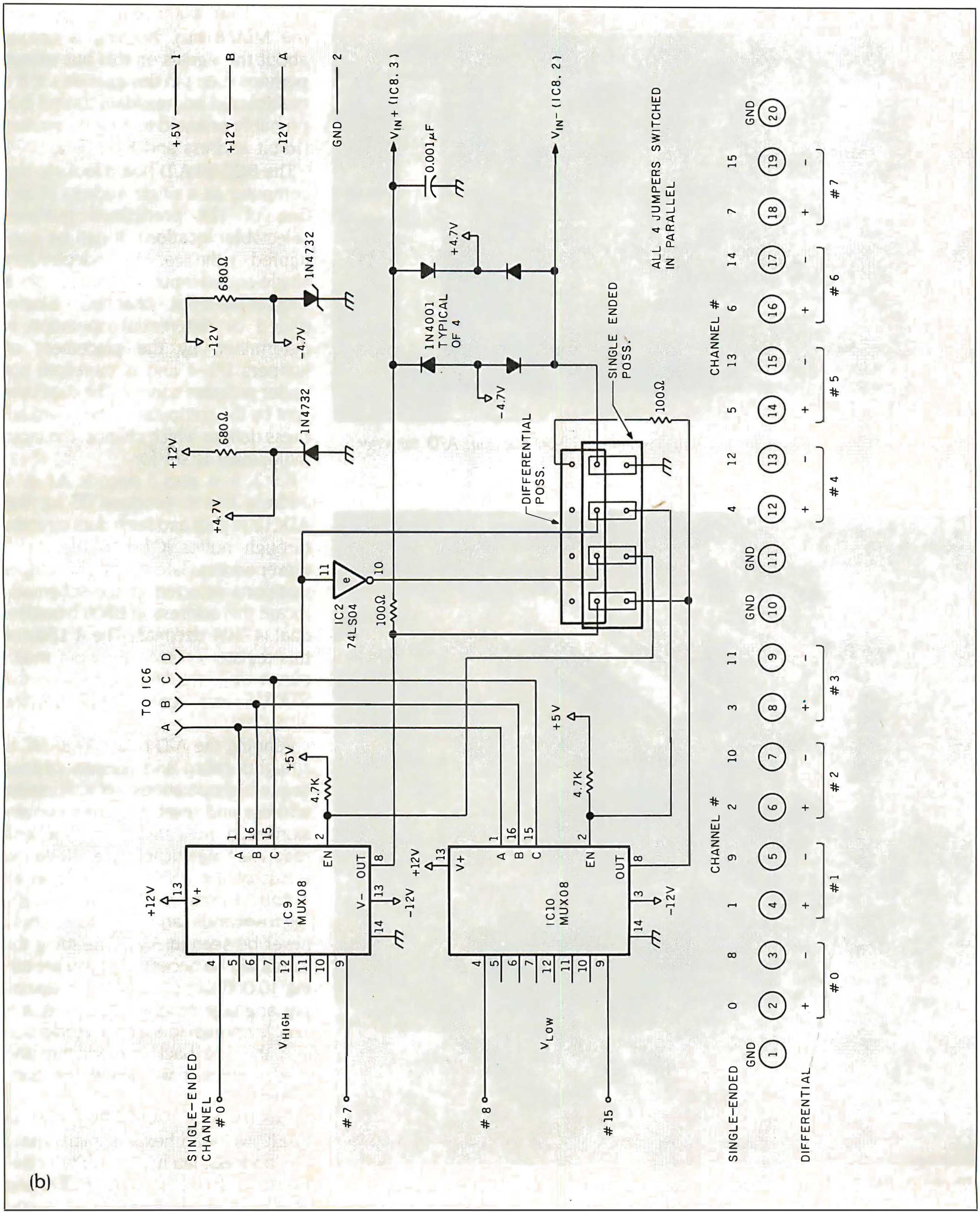


Figure 8: *Schematic diagram of the BCC-30 16-channel A/D converter board.*



(b)
SINGLE-ENDED CHANNEL #0
#7
#8
#15
V_{HIGH}
V_{LOW}
IC9 MUX08
IC10 MUX08
TO IC6
A
B
C
D
+12V
-12V
+5V
4.7K
IC2 74LS04
100Ω
680Ω
1N4732
+4.7V
-4.7V
1N4001 TYPICAL OF 4
0.001μF
V_{IN}+ (IC8, 3)
V_{IN}− (IC8, 2)
+5V — 1
+12V — B
-12V — A
GND — 2
DIFFERENTIAL POSS.
SINGLE ENDED POSS.
ALL 4 JUMPERS SWITCHED IN PARALLEL
CHANNEL #
SINGLE-ENDED
DIFFERENTIAL
GND

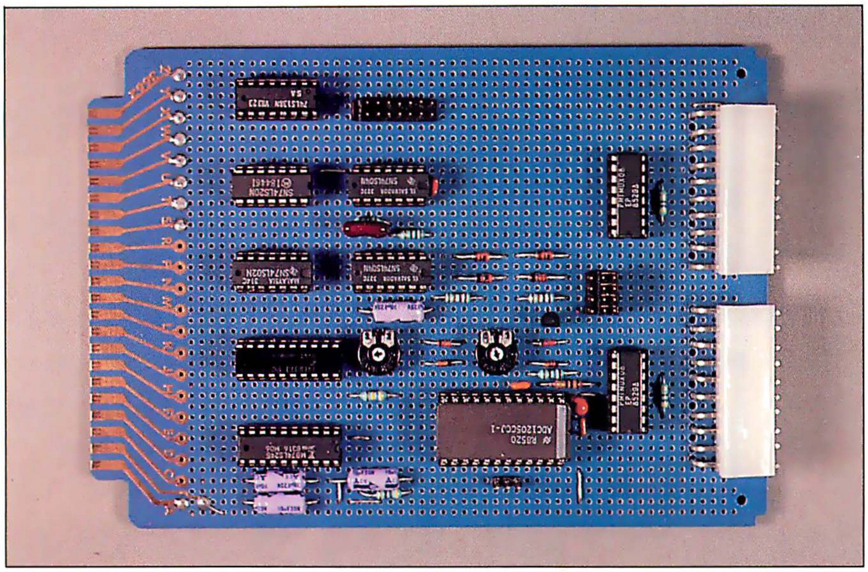


Photo 1: *Prototype of the Circuit Cellar 16-channel 12-bit plus sign A/D converter board.*

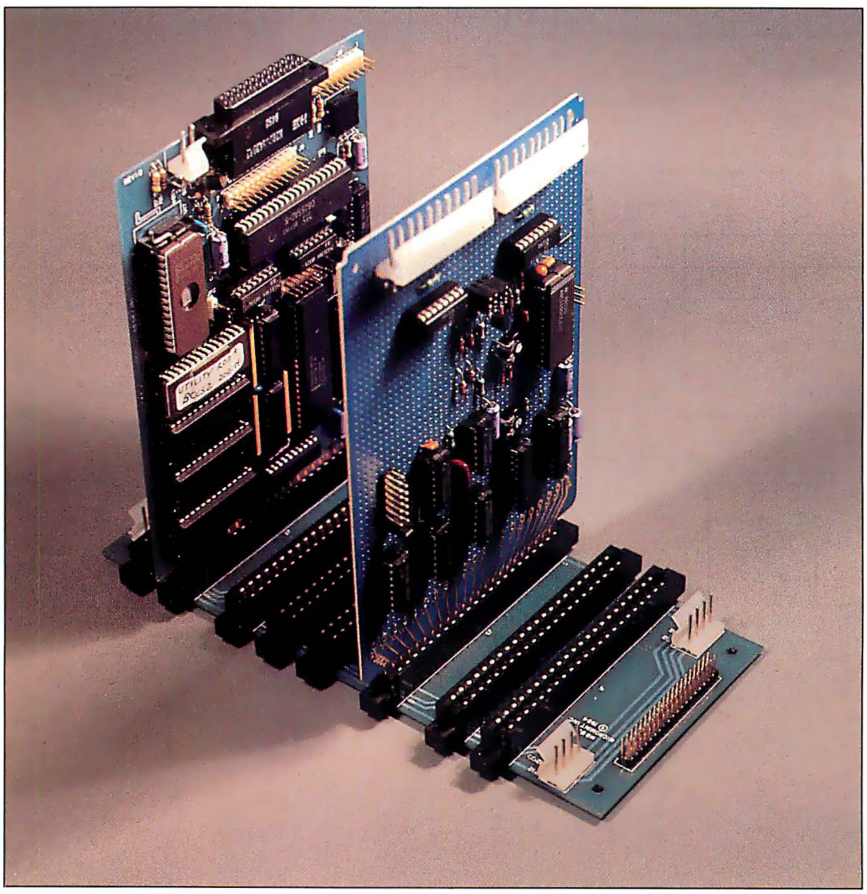


Photo 2: *The* BCC-30 A/D *board is bus-compatible with the* BCC-52 *controller board. The* BCC-30 A/D *prototype and* BCC-52 *are shown plugged into a backplane for use together.*

the "Z8 Bus" but more properly called the MMZ8 bus. Nothing is unique about the signals on this bus except perhaps their pin designations. It is a multiplexed address/data/control bus primarily oriented to 8-bit computers (16-bit address and 8-bit data).

The BCC-30 A/D board looks to the computer as a single address at any one of 128 predefined (jumper-selectable) locations. It can be configured either as 16 independent single-ended-input channels or 8 differential-input channels. Single-ended or differential operation is determined by the placement of jumpers JP1–4 and is therefore not under program control. The data byte sent by the computer to the board address defines which channel the input multiplexer is set for.

ICs 2, 3, 4, and 5 decode A8–A14 address bits to produce $\overline{CS}$ for the ADC1205 chip and latch data directed through buffer IC7 into the multiplexer address latch (IC6). The jumper positions selected in the schematic locate this address at B800 hexadecimal (47104 decimal). The 4 LSBs of this register control the input multiplexer while the fifth bit (b4) sets the $\overline{STATUS}$ level control line to the ADC1205.

Running the A/D board in BASIC is straightforward and consists of four sequential operations: set multiplexer address and reset A/D, start conversion, read most significant byte, and read least significant byte. While the status of the A/D is available as an output, a conversion takes only 100 microseconds and therefore could never be seen in BASIC (reading the status will be necessary if you are taking 10,000 samples/sec in an assembly-language program, however). It is simple enough to start the conversion and then go back immediately and read it since it will always be completed.

Executing an XBY(47104) = 18 in BASIC will load hexadecimal 12 into the address latch (the XBY() command in BASIC-52 is like PEEK and POKE in other BASICs). This corresponds to a multiplexer address of 2 and a status bit set to a logic 1

(reset). Resetting the status bit starts the conversion with an XBY(47104) = 2. The 2 bytes are then read as A1 = XBY(47104):A2 = XBY(47104). The most significant byte/least significant byte counter automatically increments on the successive reads. Summarizing, to read channel #2 (board address B800 hexadecimal), we execute code as outlined in figure 9.

A1 and A2 can then be combined to produce the desired output. I refer you to listing 1 for that procedure.

As mentioned earlier, four jumpers (JP1–4) decide whether the function of the A/D is 16-channel single-ended or 8-channel differential. All four jumpers are moved together, and all must occupy either the single-ended or differential jumper positions together. Each MUX08 (IC9 and 10) multiplexer is an 8-channel JFET-type analog switch. While CMOS (complementary metal-oxide semiconductor) switches might function in the circuit (and be about a tenth the cost), their I/O-transfer characteristics are not adequate for a 12-bit converter. The variations in resistance with input signal level would surface as measurement errors and instability. JFET multiplexers are specifically designed for this application and have very flat response curves.

Four bits from the multiplexer address latch (IC6) are directed through the jumpers to the multiplexer control lines. In the single-ended position, V_{in-} of the ADC1205 is physically grounded, and the two MUX08s sequentially address 16 input signals through it to the V_{in+}. When they are in the differential position, however, address line D is disabled, V_{in-} is removed from ground, and both V_{in+} and V_{in-} are switched through the input multiplexers. A differential input on channel #2, for example, would have V_{in} high on IC9 pin 6 and V_{in} low on IC10 pin 6 (setting channel #10 when using differential mode will enable channel #2 instead).

The remaining areas worth commenting about are the reference voltage and input protection. For a 12-bit A/D to be worth anything, it must have a precise, stable reference voltage for its internal D/A. In the BCC-30, the 5-V reference is supplied from an LM336-5 voltage reference chip. Additional diodes and a trim pot allow it to be precisely set at 5.000 V with virtually no temperature drift. Only a positive reference is required, even though the converter measures negative voltages as well.

The only "gotcha" in using the ADC1205 is input protection. While it measures +/− 5-V inputs, levels above or below +/− 5.3 V may damage the device. One method of protecting the inputs is through clamping diodes and current-limiting resistors. Using these techniques, I have connected V_{in+} and V_{in-} to a voltage source that will shunt damaging inputs away before they exceed 5.3 V. Unfortunately, if these diodes are connected to +/− 5 V, they will not begin conducting until +5.6 V and −5.6 V, respectively (germanium diodes with similar speed and power capabilities are much more expensive). I have chosen the least painful alternative by providing +/− 4.7-V Zener-generated sources to the clamping diodes that will start conducting at 5.3 V.

Presently, only a 100-ohm series

(continued)

BASIC Command	Function
XBY(47104) = 18	Set multiplexer channel #2 and set status line high to reset A/D converter.
XBY(47104) = 2	Retain multiplexer channel setting and set status line low to start conversion.
A1 = XBY(47104)	Read first (most significant) byte.
A2 = XBY(47104)	Read second (least significant) byte.

Figure 9: *Series of* BASIC-52 *statements used to read channel #2 of the* BCC-30.

Listing 1: A *sample* BASIC-52 *program to read and display channels* 0–7 *on the* BCC-30.

```
10   CLEAR
20   REM  READ AND DISPLAY A/D CHANNEL 0-7
30   REM  SINGLE-ENDED OR DIFFERENTIAL
40   REM  -5- TO +5-VOLT INPUT
50   REM
60   REM
70   N=47104 : REM BOARD ADDRESS
80   REM  STATUS BIT IS B5 - LOGIC 1 IS RESET
90   FOR A=0 TO 7 : REM  DO ALL CHANNELS 0-7
100  GOSUB 160 : REM  READ A CHANNEL
110  NEXT A : REM  NEXT CHANNEL
120  PRINT CHR(18),CHR(27),"Y" : REM  TERMITE — HOME AND CLEAR SCREEN
130  REM  DISPLAY ARRAY HOLDING CHANNEL 0-7 READINGS
140  PRINT USING (#.###),A(0),A(1),A(2),A(3),A(4),A(5),A(6),A(7),"VOLTS"
150  GOTO 20 : REM  DO IT ALL AGAIN
160  XBY (N) =A+16 : REM  RESET A/D AND SET MULTIPLEXER CHANNEL
170  XBY(N)=A : REM  CLEAR STATUS BIT TO READ DATA
180  D1=XBY(N) : D2=XBY(N) : REM  READ 12 BITS AS TWO SUCCESSIVE WORDS
190  R=0.0012207 : REM  VOLTS PER COUNT
200  IF D1>=240 THEN GOTO 230
210  A(A)=R*((D1*256)+D2) : REM  SAVE POSITIVE READING IN ARRAY
220  RETURN
230  D1=255-D1 : D2=255-D2 : REM  ADJUST D1 & D2 FOR
     TWO'S COMPLEMENT
240  A(A)=-1*R*((D1*256)+D2) : REM  SAVE NEGATIVE READING IN ARRAY
250  RETURN
```

CIRCUIT CELLAR

resistor is used in each input line to dissipate any input overvoltage. The ADC1205 converter has about a 50-kilohm input impedance so this extra resistance is unnoticeable. The series resistance can be increased further for more protection, but the temperature drift of this resistor adds errors to the system. The quantity of error depends upon the signal source impedance.

Frankly speaking, I would much rather have added a clamped-output op-amp stage, but it would have been very expensive. Remember, we are talking about 1-mV signals and 20 parts per million maximum permissible temperature drift. It hardly makes sense to add an op amp with a 30-mV offset and 200 ppm temperature drift combined with piles of who-knows-what discrete components moving in all different directions. Low-drift, low-offset, high-speed op-amp circuits are expensive.

It would be easy for me to simply provide an untried schematic of a typical protection circuit, but, as a practical matter, a properly designed and tested circuit with no offset or drift would have been a bigger project than the whole A/D board. I suggest that you simply try to limit your input range to +5 to −5 V. Half-watt 100-ohm series resistors will protect the inputs up to +/− 12 V.

While faster diodes might eventually be required in the clamping circuits shown, they are reasonably priced and adequate protection for normal use. No one wants to pay what it would take to guard against all possible circumstances. Only an idiot would try to measure the voltage across the tips of an arc welder with this board.

Conclusion

The price/performance of A/D converters is a balance of speed and resolution. There are $200 4-bit 100 million samples/sec A/D chips and $9.95 12-bit 2 samples/sec units (I won't bother to tell you how much 12 bits at 100 million samples/sec would cost). In environmental systems that have slowly varying conditions, speed is not as important as accuracy. Room temperature, for example, doesn't change so fast that you need to sample it 500 times a second. The accelerometers on a shake table, however, may need to be sampled 20,000 times a second for accurate G-force event records.

The BCC-30 has more than enough performance for most data-acquisition situations and will be finding a home in industrial control applications along with the BCC-52.

Circuit Cellar Feedback

This month's feedback is on page 403.

Next Month

I'll build a multichannel audio/video multiplexer. ■

The following items are available from

The Micromint Inc.
25 Terrace Dr.
Vernon, CT 06066
(800) 635-3355 for orders
(203) 871-6170 for information

1. BCC-30, 12-bit plus sign, 10,000 samples/sec, input range: −5 to +5 V, 16-channel A/D converter board.
   assembled and tested. . . .BCC-30, $197
2. BCC-13, 8-bit, 12,000 samples/sec, input ranges: 0 to 10 V or −5 to +5 V, 8-channel A/D converter board.
   assembled and tested BCC-13, $140
3. BCC-99 manual set. Includes all user's manuals and schematics for BCC-52, BCC-11, and BCC-21 computer/controllers and all currently available expansion boards, including serial, parallel I/O, AC/DC power I/O, and those listed above. Shipping weight 5 lbs.
   . . . . BCC-99, $29.95

All the units above are bus-compatible with the BCC-52, BCC-11, and BCC-21 computer/controllers. All units come complete with user's manual.

Please include $4 for shipping and handling in the continental United States, $10 elsewhere. Connecticut residents please include 7.5 percent sales tax.

Editor's Note: Steve often refers to previous Circuit Cellar articles. Most of these past articles are available in book form from BYTE Books, McGraw-Hill Book Company, POB 400, Hightstown, NJ 08250.

Ciarcia's Circuit Cellar, Volume I covers articles in BYTE from September 1977 through November 1978. *Volume* II covers December 1978 through June 1980. *Volume* III covers July 1980 through December 1981. *Volume* IV covers January 1982 through June 1983.

Introd
Lasog



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Team Xerox

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Q&A

Integrated software with macros and an Intelligent Assistant

Editor's note: The following is a BYTE *product preview. It is not a review. We provide an advance look at this new product because we feel it is significant. A complete review will follow in a subsequent issue.*

Q&A is a new product from Symantec (see "In Brief" on page 122) that integrates word processing and file management with a full macro facility and an effective natural-language interface, your "Intelligent Assistant." The database and word-processing modules include data merge, comprehensive report capabilities, and context-sensitive help, but it is the Assistant that distinguishes the software. With it, you have the option of addressing the database intuitively and quickly by entering ordinary English phrases and sentences. You can carry on a conversation about the data in your database, to find forms, to ask questions of the database, to view or print reports, to run predefined reports, to perform calculations on the data, or to change the information in the database. And with macros, you can speed requests by defining keys as commonly used words and phrases. You can thus bypass the more formal searching, reporting, and updating procedures in most database applications and in Q&A's own database module.

YOUR INTELLIGENT ASSISTANT

The Assistant has a built-in vocabulary of over 400 words (see table 1 for a partial list), and it automatically learns field names and the contents of the database. If you desire, you can also train your Assistant to comprehend your parlance in eight quick lessons. By so doing, you can increase the number of words that the Assistant understands and provide for much more personalized sessions.

From the Assistant's main menu (see photo 1) you can get acquainted with your new helper through a series of short help screens (and you can rename it to your liking—I chose the name Duncan), you can elect to train or retrain the assistant, or you can ask it to do something.

A SAMPLE SESSION

Let's follow a session with the sample database, Realty, which contains addresses and descriptions of 47 bed-and-breakfast units in the United States. The fields include owner's name, address, number of beds, number of baths, rent, amenities, type, and commission.

After loading in the database, the Assistant asks you to type your request in English (see photo 2).

Me: Where can I get a room?
Duncan: Shall I do the following? Create a report showing the address, city, state, zip, and bed from *all* the forms?

The bottom of the screen presents my options. For example, you can dump the output to the screen or to a printer, edit individual forms, or focus the search further. Let's try something a bit more practical.

Me: Are there any units for rent with more than 1 bed and a pool?

After 10 seconds on an IBM AT, with Duncan highlighting its progress through the sentence, it responds:

Duncan: Shall I do the following? Create a report showing the monthly rent and the address and the city from the forms on which the bed > 1 and the amenities include "pool" sorted by monthly rent?

I'm not sure why it sorted by rent, but I got the information I requested. The report included 17 units sorted from the highest to the lowest rent. Finally, I tried another approach.

Me: Show me the forms for the units with between 2 and 5 baths.
Duncan (7 seconds later): Shall I: Select and view the forms on which the bath is > = 2 and < = 5?

It's hard not to be impressed. The Assistant answers many "Are there. . ." questions with "Yes, press return to see the forms," and "How many. . ." questions with a numeric answer. You can perform calculations, ask follow-up questions, ask to see specific forms, ask date-related ques-

tions ("Who was hired after June 1, 1985?"), and sort. With a larger database, you might want to find the average number of beds in Boston, sort the cost of condominiums with two beds and a bath, or view the list of owners with last names beginning with "D."

And you can also use the Assistant to create or delete forms. For example, you could type "Fill in a new form with 5 Main Street in the address field" or "Delete all forms with no addresses" and the Assistant will comply. To modify a form, try "Change Paul John's street address to 5 Main Street," or "Increase all rents by $5."

Clearly, the possibilities are limitless, but I did have some problems. The Assistant tended to be a bit unforgiving with my typographical errors. It does permit you to edit or define words that it does not understand, but it does not have a built-in spelling checker to offer possible interpretations of your entry. Moreover, after you have corrected your error, it begins its interpretation of your request at the beginning, not where it encountered the problem. And if you are well accustomed to databases, you may long for faster access to the data. The File module, which I describe in detail later, permits more conventional inquiries. Although I found that by truncating my requests ("3 beds" or "sort beds by state") and by using abbreviations that the Assis-

(continued)

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Display	Calculate	Search/Sort	Edit	Adjective	Comparative	Superlative
display	add	alphabetical	blank	big	above	biggest
find	difference	containing	enter	low	larger	least
get	divide	descending	erase	many	less	littlest
list	average	and	change	few	below	bottom
make	bottom	ascending	create	great	bigger	fewest
print	count	before	define	high	greater	greatest
report	half	early	expunge	much	littler	lowest
run	cut	begin	delete	large	fewer	highest
search	increase	excluding	new	small	lower	maximum
show	decrease	between	empty	little	higher	largest
table	maximum	fewer	remove		more	minimum
	mean	find	replace		over	most
	minimum	first	set		smaller	smallest
	multiply	get			under	top
	percent	greater				
	plus	higher				
	product	including				
	quotient	increasing				
	raise	last				
	ratio	late				
	remainder	least				
	subtract	lower				
	sum	not				
	total	or				
	twice	order				
		recent				
		reverse				
		search				
		start				
		through				
		top				
		under				

Table 1: *A list of some of Q&A's built-in vocabulary sorted into categories.*

tant understands ("WNIC" for "with no identification columns"), I got reports and got to the data quickly.

TEACHING YOUR ASSISTANT

One other problem was easy to solve. I asked about "radar ranges," but discovered that Duncan only understood "microwaves," the precise entry in the amenities field. Immediately, however, Duncan gave me an opportunity to look at all the words in its dictionary and to define the new word as a synonym for the term it knew. You can just as easily delete a synonym from the list. Alternatively, you can tell the Assistant to "Define 'radar range' as 'microwave'" or try more complex synonyms like "Define 'home' as 'address, city, state.'" One of the nicest features is using synonyms to define reports. For example, if you enter "Define 'bedsort' to be 'address, state, zip code, and rent, sorted by bed,'" you could later enter "bedsort in Massachusetts."

Formal schooling for your Assistant is only slightly more involved, but by conducting the lessons, you can personalize your relationship with the Assistant (see photo 3). The eight lessons involve teaching the Assistant about the database. You can identify units of measure, words that generally describe the purpose and nature of the database, words that are generally synonymous with each field name, and fields that hold locations, names, or values. You can also specify the default columns that you want displayed in every report.

Two lessons are more advanced. One teaches adjectives to the Assistant. For example, you could define "young" as a low age, or "rich" as a high income. In each case, the adjectives would apply to a specific field, allowing the Assistant to make judgments like younger ("Who is younger than Jackson?"), youngest, richer, and richest. The final lesson allows you to associate verbs with particular fields. For example, by associating "earn" with a salary field, you could ask the Assistant "Who earns more than $30,000?" The Assistant has provision for learning irregular verbs.

IN BRIEF

Name
Q&A

Type
Integrated software, including word processor, database manager, report generator, and a natural-language query system. Works with single flat data files.

Manufacturer
Symantec Corporation
10201 Torre Ave.
Cupertino, CA 95014
(408) 253-9600

Price
$295
$349 with a 256K-byte RAM board
$50 trade-in policy for some database managers

Format
Three 5¼-inch floppy disks

Computers
IBM PC, XT, AT, or compatibles with a minimum of 512K bytes of RAM and two disk drives. A hard disk is preferred.



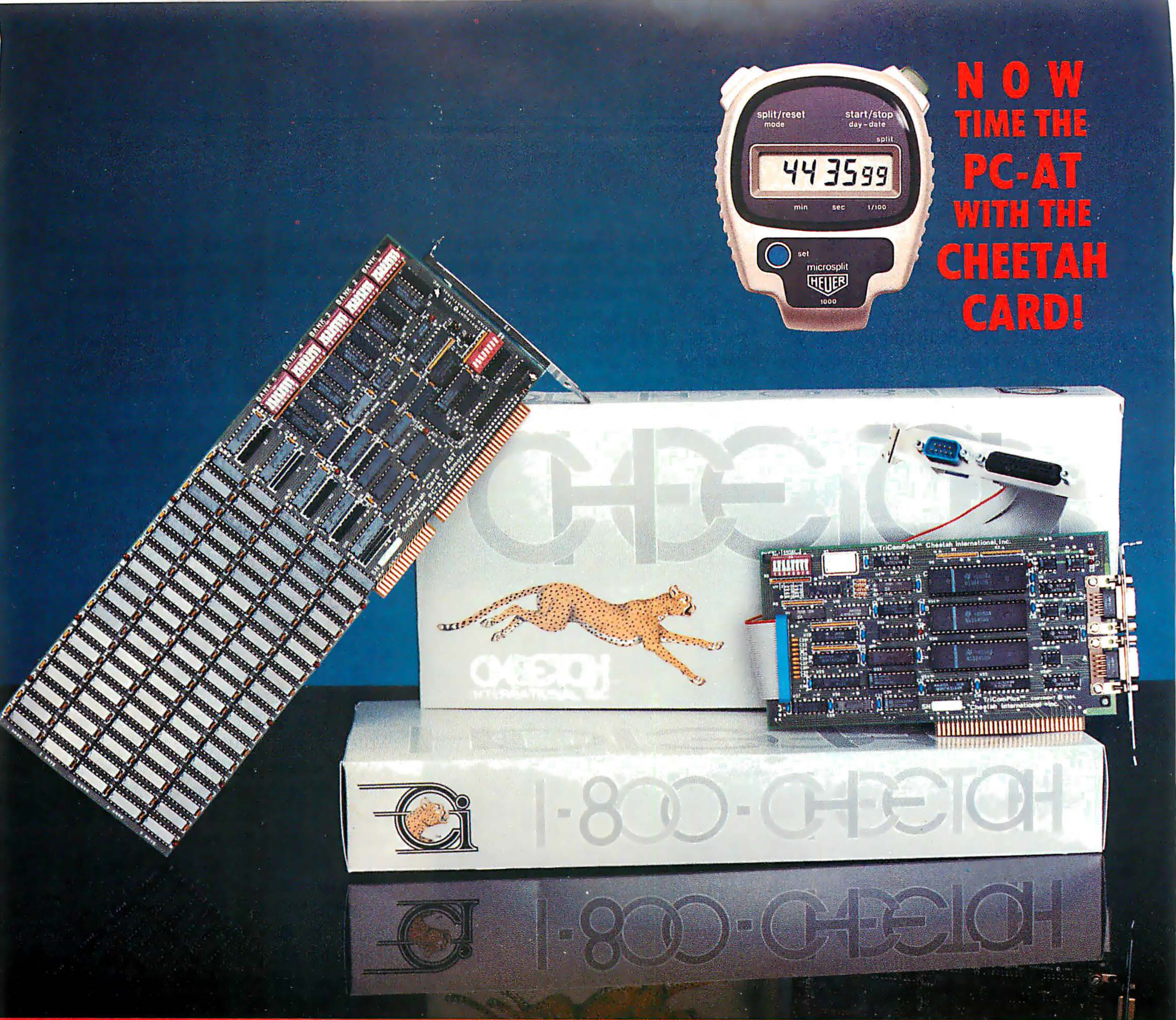
Photo 1: *The Q&A main menu.*

INTEGRATED MODULES

Q&A contains four other integrated modules, Write, File, Report, and Utilities. You select the module you want from Q&A's main menu. All of the modules use the screen format and menu structure of pfs:File.

Write provides a comfortable word-processing environment as well as "merge printing." From the main Write menu, you can define a new or edit an existing document; set page di-

(continued)



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mensions, margins, and type size; clear a document from memory; print the document; or use three DOS functions (copy, delete, and rename). Write saves text in ASCII; therefore, you could, if you desire, use your favorite editor and only then make use of Q&A's merge capabilities. Nonetheless, Write is full-featured. In addition to most conventional features, like a range of block moves, headers and footers, integrating ASCII text within existing documents, and adequate printer support, Write includes on-screen page breaks, macros, word counts, context-sensitive help, a limit of approximately 30 pages of text per document, and line and box drawing. You can also customize commands in a default file. You can save a personalized default file in different directories for different kinds of documents. Windowing, footnoting, and columnar commands are the only conspicuous features that are missing.



Photo 2: *Using the Intelligent Assistant.*

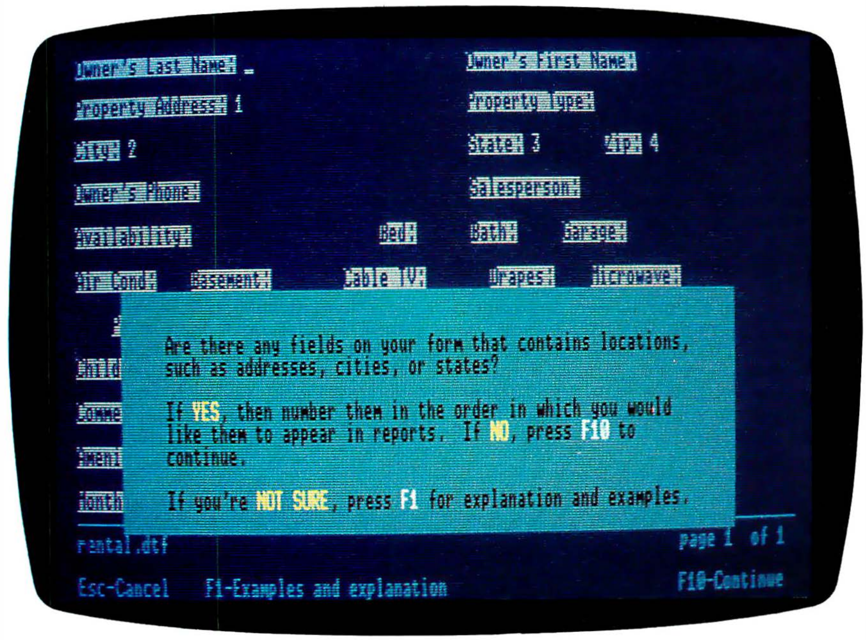


Photo 3: *The third lesson for the Assistant.*

Write does not work directly with the Intelligent Assistant, but you can use the merge capabilities to insert Q&A data into Write documents. You need only place *field name* within the text to access the data, and there are a variety of text-formatting commands to smooth the printing of merged documents. To print the document, you select Print at the main Write menu. You can then select among several options, including the selection of the database to be used, the number of pages and copies, line spacing, and justification.

You can use File, a full-featured database, to build single flat files for use with the Intelligent Assistant or to search for and retrieve data directly. From the main File menu, you can design (or redesign) the database, add data, search, update, mass-update, copy, delete, and print. Forms can be up to 10 screen pages long; each screen page contains 21 lines, or three screen pages per 8½- by 11-inch sheet. You can have up to 1980 characters per field, 2400 fields per record, and up to 16 million records per file. Each field can be up to one screen in length. You can sort (ascending and descending) on up to 25 fields and index on up to 120 fields. Field types include text, number, money, keyword, date, hours, and yes/no.

File's procedures are more conventional and formal than the Intelligent Assistant's, but for data entry and some reports, you will undoubtedly prefer its options. Within File, you can add punctuation and symbols, you can perform date and time arithmetic, and you can include programming statements (including IF. . .THEN, IF. . .THEN. . .ELSE, AND, OR, NOT,

(continued)

and INT) to update fields conditionally or to control the order of data entry. You can customize field-specific help screens to provide context-sensitive aid in entering the data, a useful feature when fields restrict data in some way. You can also use colors, shading, and underlining, perhaps to set off the current field or the field labels. Lookup tables let you construct and edit a table of values; you could, for example, construct the table to hold relevant tax information for different states or countries. Entries in the table cannot exceed 69 characters. The Print feature is also more versatile than the Intelligent Assistant's. For example, like most database managers, File allows you to print mailing labels and to design and reuse specialized forms.

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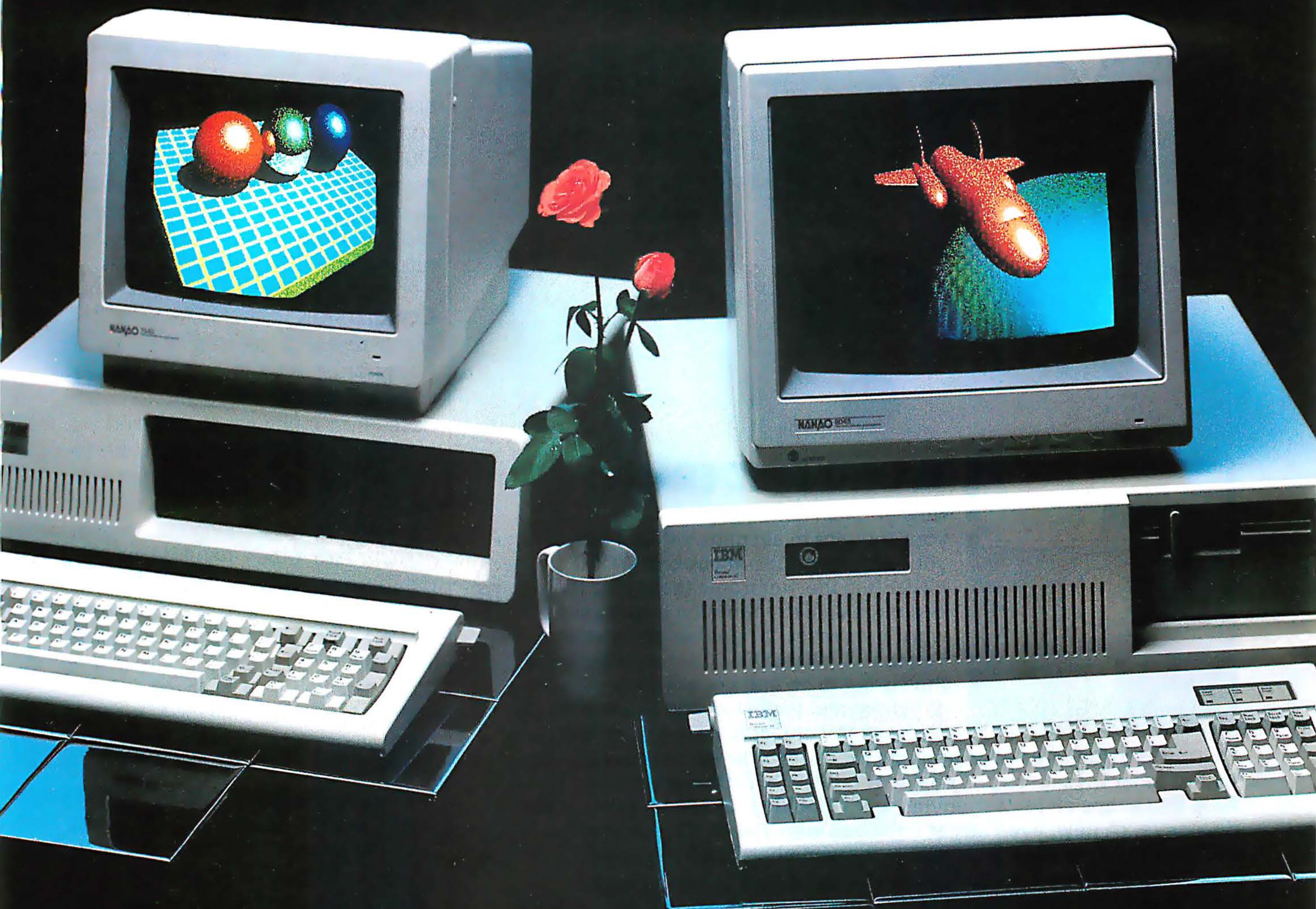
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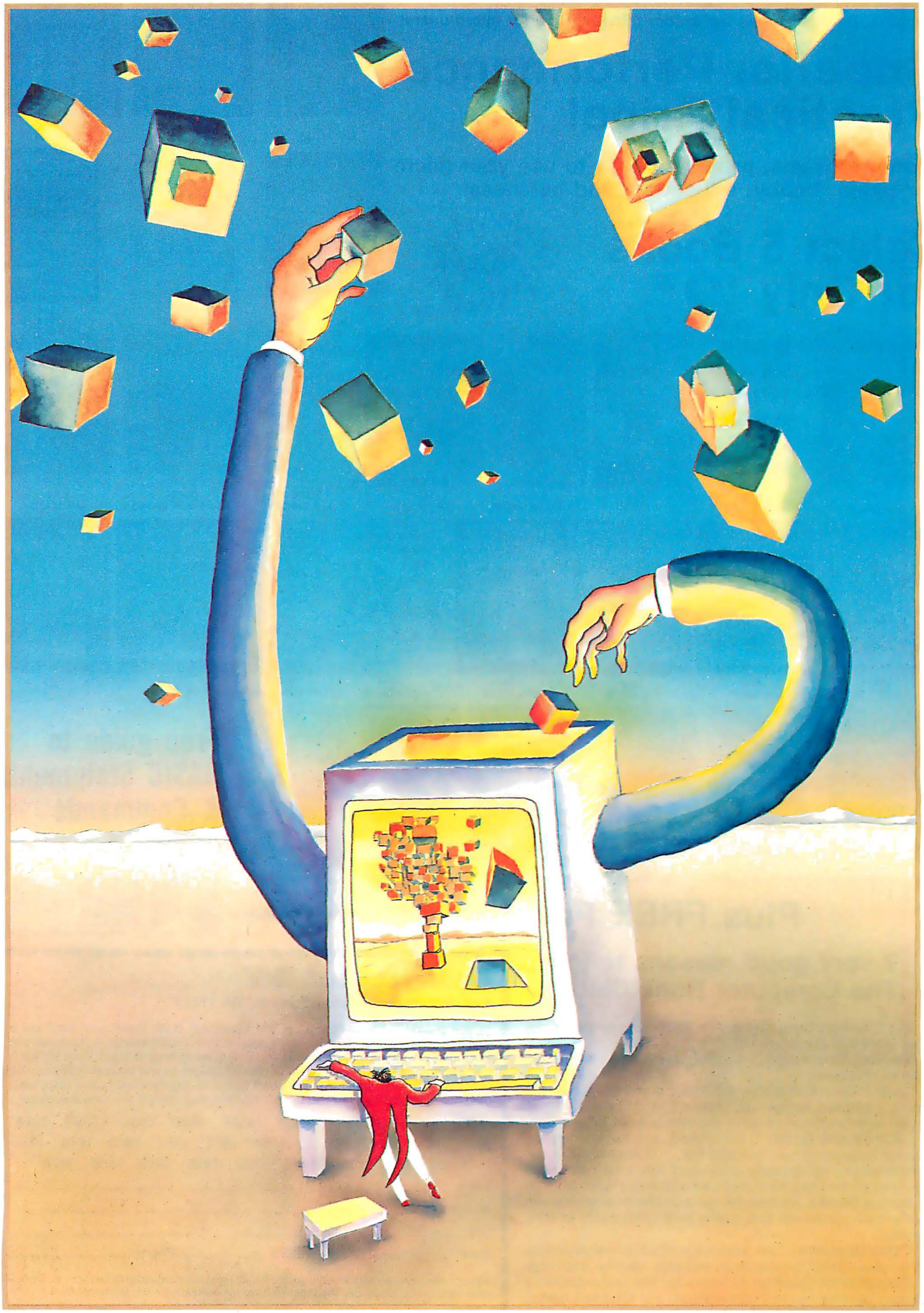
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CONCLUSION

Much research on natural-language query processing is centered on accessing data from relational databases in a multiuser, networked environment. Q&A draws from the research, though the software manipulates only single flat files and has no multiuser or networking capabilities.

There are other natural-language database products for the microcomputer market (see "CLOUT and SALVO" by George Bond, October 1984 BYTE, page 279), but most are either front ends or have much more restrictive features than Q&A. With full integration, macros, and an Intelligent Assistant capable of searching and sorting as well as updating the database, Q&A may go far in attracting users who are tired of the programming-like formalism often required to retrieve data and organize reports.

Nonetheless, natural-language query systems have inherent limitations. Processing the query takes time. It may be hard for some to justify the time required to teach the Assistant, and individual expert users will undoubtedly be better served by raw programming power. And Q&A is not the ultimate natural-language product, since it doesn't support relational queries and isn't meant for use in a multiuser environment. Still, with the Intelligent Assistant, you can effectively explore the relationships in your data without having to grumble about database syntax. Q&A gets the job done in an enjoyable way. ■



ILLUSTRATED BY JOHN S. DYKES

A SIMPL COMPILER PART 2: PROCEDURES AND FUNCTIONS

BY JONATHAN AMSTERDAM

Procedures and functions are a boon for programmers, but they're tricky to compile

Last month, I described the construction of a compiler for the high-level language SIMPL, but I omitted any description of the part of the compiler that handles procedures and functions. This month, I'll fill that gap.

The SIMPL compiler I wrote translates SIMPL, a Pascal-like language, into VM2 assembly language. VM2 is a hypothetical computer that I wrote a simulator for in "Building a Computer in Software" (October 1985 BYTE, page 112). I described an assembler for VM2 in my November 1985 article (page 112). The routines—my collective term for procedures and functions—of SIMPL are similar to those of Pascal, except that a value is returned from a function using a RETURN statement rather than by assignment to the function name. The syntax of routines is presented in figure 1, and a SIMPL program using a function can be found in listing 1a.

THE CHALLENGE OF ROUTINES

What makes compiling routines so difficult? Listing 1 shows a SIMPL program that calculates the factorial of a number, using a function called fact. The factorial of a nonnegative integer n is $n*(n-1)*(n-2)* \ldots *$ 1. The fact function is recursive; it says that the factorial of n is equal to n times the factorial of $n-1$ and that the factorial of 0 is defined to be 1. To see what has to be done to compile this program, first consider what the run-time behavior of the program ought to be. The following four things have to be done when calling fact.

1. When the statement WRITE(fact(n)) is executed, control has to transfer to the code constituting fact.
2. The argument n has to be passed to the function. Somehow, the actual parameter, the value of n in the call to fact, must be connected (or bound) to the formal parameter, n, that appears in the function definition.
3. It is necessary that fact return to the proper place in the main program and that its result be made available. A function call should act as if it were replaced by its result in the program text. If the call to fact produced the result 6, the program should behave as if the call to fact were simply replaced by the number 6, yielding the statement WRITE(6).
4. Storage has to be found for fact's local variable, temp.

(continued)

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To handle the control transfer, a simple BRANCH instruction will suffice. If we provide fact with a return address—the memory address of the instruction just after the call—fact will know where to branch to when it's finished. That takes care of transferring control.

How about storage allocation? One solution, often used in FORTRAN compilers, is to allocate enough space with each procedure or function to hold that routine's arguments and locals, plus an additional word of storage for the result of a function. In this case, three words would be allocated: one for the argument *n*, one for temp, and one for fact's return value. The compiler would assign these memory locations while compiling fact; it would remember them in the symbol table and use them to generate references to the argument, local, and return value.

```
routine    ::= proc | func
proc       ::= PROCEDURE id {formals} ; {vars} <routine> block;
func       ::= FUNCTION id {formals} : type ; {vars} <routine> block;
formals    ::= ( <decl ;> decl)
```

Figure 1: *The syntax of* SIMPL *routines. A block is a list of statements surrounded by* BEGIN *and* END; *a* decl *is a variable declaration; and vars indicate the keyword* VAR *followed by one or more* decls. *Curly braces around an item indicate that the item is optional. Angle brackets indicate zero or more repetitions of the item are permitted.*

Listing 1: *(a) A* SIMPL *program for calculating the factorial of a number. (b)* VM2 *assembler code generated by the compiler from (a).*

(a)

```
PROGRAM factorial;
VAR n:INTEGER;

FUNCTION fact(n:INTEGER):INTEGER;
VAR temp:INTEGER;
BEGIN
    IF n = 0 THEN
        RETURN 1;
    ELSE
        temp := fact(n-1);
        RETURN n*temp;
    END;
END;

BEGIN
    READ(n);
    WRITE(fact(n));
END.
```

(b)

```
    BRANCH factorial
n:  0
fact:
    SETSP   1
    PUSHL   0, 3      ; n
    PUSHC   0
    EQUAL
    BREQL   L1
    PUSHC   1
    FRETURN 1
    BRANCH  L2
L1:
    PUSHL   0, 3      ; n
    PUSHC   1
    SUB
    CALL    fact, 1
    POPL    0, -1     ; temp
    PUSHL   0, 3      ; n
    PUSHL   0, -1     ; temp
    MUL
    FRETURN 1
L2:
    PUSHC   0
    FRETURN 1
factorial:
    RDINT
    POPC    n
    PUSH    n
    CALL    fact, 0
    WRINT
    HALT
```

This design is simple and elegant. Unfortunately, it does not handle recursion. Because this scheme assigns a fixed amount of memory to each routine, it implicitly assumes that a routine can use only one set of arguments and locals at a time. Each time a routine is called recursively, a new invocation is set up using the same code but different values for the arguments and locals. In the simple scheme above, the values of the first invocation of a recursive routine will be overwritten by the values of the second invocation.

It is necessary to allocate new memory locations each time a recursive routine is called. But it's impossible for the compiler to predict the amount of storage a recursive routine might need, because the compiler can't determine how many recursive calls of a given routine would occur when the program is run. Therefore, this storage allocation must take place at run time, not compile time. You need to decide at compile time how to reference the arguments and locals of the routine and compile the references into the code for the routine. How can this be done?

Activation Records

The solution to this problem involves a data structure called an activation record, which is a contiguous region of memory that contains all the variable information needed for a routine's invocation. It holds the arguments, locals, and a space for the return value for functions. It also holds the return address and some pointers to other activation records I'll describe later. All the activation records for a given procedure have the same format, but their contents differ from invocation to invocation.

The run-time behavior of a program with routines is as follows: Each time a routine is called, storage for a new activation record is allocated. After the activation record is allocated, it is filled with the values of the arguments passed by the call and with the return address. Control then transfers to the called routine. When the routine

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Listing 2: *(a) A SIMPL program illustrating nested routines.*
(b) VM2 assembler code generated by the compiler from (a).

(a)

```
PROGRAM P;
VAR a, b:INTEGER;

  PROCEDURE Q;
  VAR b, c:INTEGER;
    PROCEDURE R;
    VAR b, d:INTEGER;

    BEGIN { R }
       b := 3;
       d := 3;
       WRITE('\n','R',':',' ',a,b,c,d);
       IF c > 1 THEN
         c := c-1;
         R;
    END;
    END;

  BEGIN { Q }
    b := 2;
    c := 2;
    R;
    WRITE('\n','Q',':',' ',a,b,c);
  END;

BEGIN {P}
   a := 1;
   b := 1;
   Q;
   WRITE('\n','P',':',' ',a,b,'\n');
END.
```

(b)

```
    BRANCH  P
a:    0
b:    0
R0:
    SETSP   2
    PUSHC   3
    POPL    0, -2  ; b
    PUSHC   3
    POPL    0, -1  ; d
    PUSHC   '

    WRCHAR
    PUSHC   'R
    WRCHAR
    PUSHC   ':
    WRCHAR
    PUSHC   '
    WRCHAR
    PUSH    a
    WRINT
    PUSHL   0, -2  ; b
    WRINT
    PUSHL   1, -1  ; c
    WRINT
    PUSHL   0, -1  ; d
    WRINT
    PUSHL   1, -1  ; c
    PUSHC   1
    GREATER
    BREQL   L1
    PUSHL   1, -1  ; c
    PUSHC   1
    SUB
    POPL    1, -1  ; c
    CALL    R0, 1
L1:
    RETURN  0
Q:
    SETSP   2
    PUSHC   2
    POPL    0, -2  ; b
    PUSHC   2
    POPL    0, -1  ; c
    CALL    R0, 0
    PUSHC   '

    WRCHAR
    PUSHC   'Q
    WRCHAR
    PUSHC   ':
    WRCHAR
    PUSHC   '
    WRCHAR
    PUSH    a
    WRINT
    PUSHL   0, -2  ; b
    WRINT
    PUSHL   0, -1  ; c
    WRINT
    RETURN  0
P:
    PUSHC   1
    POPC    a
    PUSHC   1
    POPC    b
    CALL    Q, 0
    PUSHC   '

    WRCHAR
    PUSHC   'P
    WRCHAR
    PUSHC   ':
    WRCHAR
    PUSHC   '
    WRCHAR
    PUSH    a
    WRINT
    PUSH    b
    WRINT
    PUSHC   '

    WRCHAR
    HALT
```

returns, the storage for the activation record is deallocated.

How are references to arguments and locals handled? Instead of wiring an absolute address into the routine's code, the compiler generates an offset from the current activation record. The offset is added to the address of the current activation record to get the address of the variable being referenced. Since all activation records for a given routine have the same format, a given offset will pick out the same variable regardless of the invocation.

The current activation record is referenced with a new register I have added to the VM2 machine. This register is called the frame pointer (FP). The FP always points to the current activation record. Each time a routine is called, VM2 needs to save the current value of the FP and set the FP to point to the new activation record. It is convenient to save the old FP in the new activation record. When the routine returns, VM2 sets the FP back to the old value. These manipulations ensure that the FP always points to the activation record of the routine currently being executed.

A new activation record must be allocated on each call of a routine, and it should be freed when the routine returns, otherwise all the machine's memory would eventually be consumed. Activation records can be allocated on a stack—the same stack VM2 uses for almost everything else it does—and can be freed by simply popping the stack. In fact, another name for an activation record is a stack frame, from which the name "frame pointer" comes. You may recall from my discussion of stacks in "Building a Computer in Software" that pushing and popping involve little more than incrementing and decrementing the stack pointer. You could hardly hope for a more simple and efficient storage-allocation scheme.

Nested Routines

The scheme for compiling routines as outlined so far does not handle

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SIMPL's feature of nested routines. Take a look at the SIMPL program in listing 2a, which makes use of nested routines. It illustrates how you can place the definitions of other routines between the local-variable declarations and the body of a routine, just as you can place routines between the global-variable declarations and the main program body. Nesting affects the scope or visibility of identifiers, that is, which identifiers—variables and routine names—are available to different parts of the program. Let us define the lexical level of a point in the program as its depth of nesting. In listing 2a, global variables are declared at lexical level 0, variables local to procedure Q are at lexical level 1, and variables local to procedure R are at lexical level 2. Then, the rules governing scope in SIMPL are easily stated: A routine has available to it all identifiers declared in the routines that enclose it and none of the identifiers declared in routines nested within it. Furthermore, if two identifiers have the same name, the one at the highest lexical level is the one that is visible to a routine.

Running the program in listing 2a results in the following output:

R: 1323
R: 1313
Q: 121
P: 11

Procedure R, being the innermost procedure, can access the global variable *a*; the variable *c*, which is local to procedure Q; and its own local variables *b* and *d*. R can also call both itself and the procedure in which it is nested, Q (R does not call Q in this example). Q cannot access any of R's variables, but it can access *a* and its own locals, and it can call R. The main program can access only global variables and can call Q. The variable *b* provides an example of how variables with the same name hide, or shadow, one another. Each of the three occurrences of *b* in the program refers to a different variable. The appearances of *b* within R and Q refer to local variables of those procedures and have the values 3 and 2, respectively. The occurrence of *b* in the main program refers to the global variable *b*, and its value is 1.

R's access to *c* causes a problem for the routine-calling scheme I outlined above. If *c* were a global variable, it would be accessible directly by name; if it were local to R, it could be found at some fixed offset from the FP. But *c* is neither local to R nor globally visible from P. I have not indicated how such nonglobal nonlocal variables can be accessed.

Before I proceed to the solution, note that at the time it is accessed by R, the variable *c* must be residing somewhere on the stack because, by the visibility rules discussed above, Q has to be called before R can be; it is only from within the definition of Q that R is visible at all.

You may recall that the activation record for R contains the value of the FP for R's caller. In this case, R's caller is Q, so the old FP is a pointer into Q's activation record. It would seem you need only follow the old FP to get to nonlocal nonglobal variables.

This will not work, however, because other routines besides Q can call R; in particular, R can call itself. In this case, the old FP for the second invocation of R points to the activation

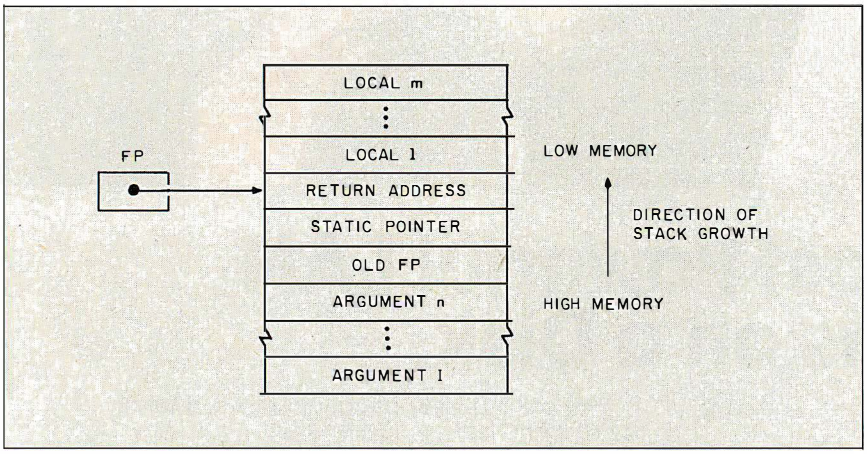


Figure 2: *The structure of an activation record for a routine with n arguments and m local variables.*

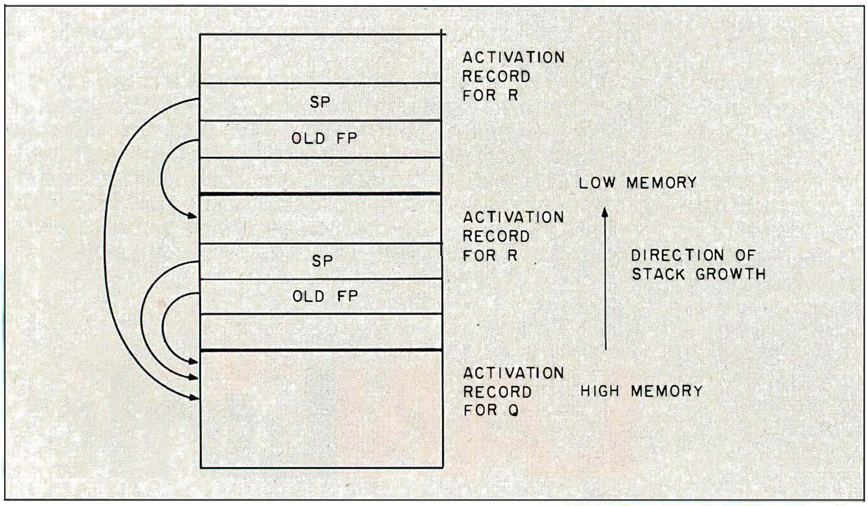


Figure 3: *The structure of the stack when* Q *calls* R *and then* R *calls itself showing the static* (SP) *and dynamic* (FP) *pointers.*

record for the first invocation of R, not to Q's activation record, so following the old FP would not get us to Q, but merely to another copy of R. We would need to follow the chain of frame pointers back twice to get to Q.

Static Pointers

In essence, the problem with following the FPs to find nonlocal nonglobal variables is this: The saved FPs indicate the dynamic structure of the program, its run-time behavior: who calls whom. To find variables, the so-called static structure is needed: who's defined inside whom.

The solution I have adopted is to maintain a static pointer (SP) in each activation record in addition to the value of the caller's FP (sometimes called the dynamic pointer). The SP always points back to the most recent activation record of the routine in which the current routine was defined; for instance, the SP in R's activation record always points to an activation record for Q, regardless of who called R. The activation-record format for a routine with *n* arguments and *m* local variables is shown in figure 2. Figure 3 illustrates the structure of the stack when static and dynamic pointers are used. Note that it is sometimes necessary to follow several static pointers to get to the desired variable. For example, if a procedure S were defined inside R and accessed the variable *c*, the SP in S's activation record would be followed, leading to an activation record for R; then, R's SP would be followed, leading to the desired activation record for Q. The number of static pointers to follow is the difference in lexical levels between the point of call and the callee.

Calling Mechanism in Action

Now that all the pieces of the routine-calling scheme have been described, let's put them into place by seeing what happens when the program in listing 2 is executed. You may want to glance at figure 4 during this discussion.

The main program begins by calling Q. First, the current value of the FP is pushed, followed by the SP, and the FP is set to the current value of the stack pointer. Since Q is called from the main program, it is not necessary to save the FP on the stack or to compute the SP, but I do it anyway since it's easier to implement this calling mechanism if a call from the main program isn't treated as a special case. Next, the return address, which can be calculated from the value of the program counter at the time of the call, is pushed onto the stack, and the computer branches to the beginning of Q (see figure 4a).

Q begins by pushing two zeros onto the stack. This serves to allocate a word on the stack for each of Q's local variables and at the same time to initialize those variables to 0. The body of Q begins execution by setting its local variables, *b* and *c*, to 2. Then, R is called by the same mechanism as before: First, the FP is pushed onto the stack, the SP is computed by following the chain of static pointers as many times as the difference in lexical levels between the point of call and R, and the value of the FP for the activation record at that place in the stack is pushed. Since the definition of R is at the same lexical level as the body of Q, no static pointers need be

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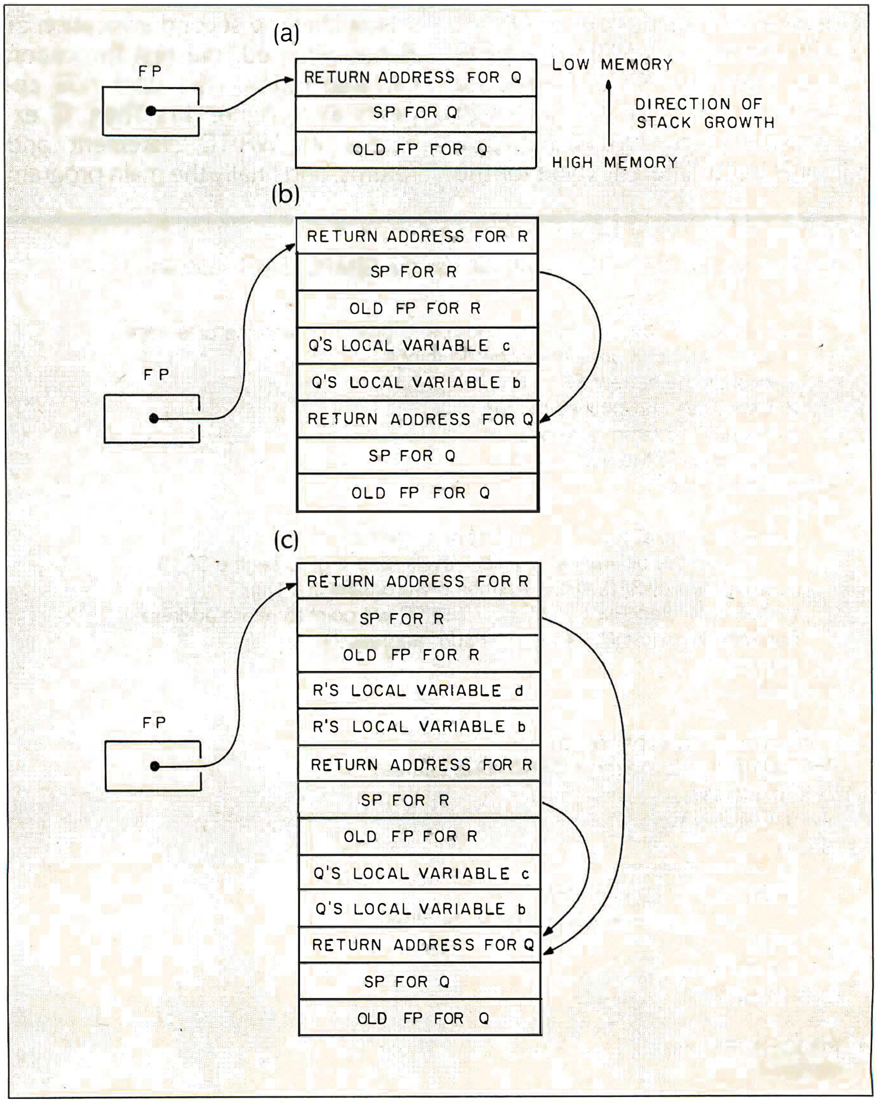


Figure 4: *The run-time behavior of the program in listing 2. See the text for details.*

followed, and the FP value for Q is pushed as the SP for R's activation record. FP is then set to the stack pointer, the return address is pushed, and control transfers to procedure R (see figure 4b).

After pushing and initializing its local variables, R executes its WRITE statement, then tests the value of Q's local variable *c*. Since Q set *c* to 2, the statements within the IF statement are executed. First, *c* is decremented, then R is called recursively. To begin the recursive call on R, the FP is again pushed onto the stack and the new SP calculated. Now, since this activation record for R is one lexical level deeper than R's definition, a single SP is followed; this leads back to Q's activation record, so the FP value for Q is again used as the SP for this second invocation of R. Note that although the activation record for each invocation of R has a different value for the old FP, they have the same value for the SP. Next, the FP is set to the current value of the stack pointer, the return address is pushed, and control transfers to the body of R for the second time (see figure 4c).

In the second invocation of R, R's local variables are pushed onto the stack and then the WRITE statement is again executed. R tests *c*, but this time it is not greater than 1, so the code within the IF statement isn't executed. The return process is the inverse of the call: The stack pointer is set back to where it was before the call, and the FP is restored to its old value. At this point, the stack again looks as it does in figure 4b.

Now that the second invocation of R has returned, the first invocation can also return. (The stack now appears as in figure 4a.) Then, Q executes its WRITE statement and returns, and finally the main program does a WRITE and the program ends.

What I've just described differs in two minor ways from the scheme as I originally presented it. First, although for reasons of conceptual simplicity I described the activation record as being allocated all at once, it in fact is allocated piecemeal, a push at a time: the arguments (although in this example there were none), the FP, the SP, and the return address. Second, it's somewhat more convenient for my purposes to have the FP point to the middle of the activation record instead of to the beginning. This means that some offsets from the FP will be negative and others positive.

Listing 3: *The Modula-2 source code for the* SIMPL CALL *statement.*

```
(* CALL takes two arguments, the address to branch to and the difference
    in lexical levels. It does the following things:
    1. Pushes the current FP
    2. Computes and pushes the SP
    3. Pushes the return address
    4. Branches to the address. *)
PROCEDURE call;
BEGIN
    pushWord(framePtr);           (* save current FP *)
        (* use the difference in lexical levels (2nd arg) to set the SP *)
    pushWord(followSP(CARDINAL(memory[programCtr + 1])));
    framePtr := stackPtr;            (* FP will point to return address *)
    pushWord(programCtr + 2); (* return address *)
    branch;
END call;

(* Follows the static-pointer chain. *)
PROCEDURE followSP(num:CARDINAL):address;
VAR fp:address;
    n:CARDINAL;
BEGIN
    fp := framePtr;
    FOR n := 1 TO num DO
        fp := address(memory[fp + SPoffset]);
    END;
    RETURN fp;
END followSP;

PROCEDURE branch;
BEGIN
    programCtr := address(memory[programCtr]);
END branch;
```

SOME NEW INSTRUCTIONS

A compiled program's code would be long and messy indeed if it had to worry about every manipulation of static pointers and activation records. Instead, I'm going to push all this complexity down into the virtual machine, VM2, and hide it behind five new VM2 instructions.

The first and most complicated is CALL, which takes two arguments: the memory address of the beginning of the routine's code and the difference in lexical levels between the caller and callee. It performs all the operations necessary when one routine calls another: saving the return address and FP on the stack, setting the SP, setting the FP register, and branching to the routine. Because CALL is so complex, I have provided the Modula-2 source code for it in listing 3.

The instructions PUSHL and POPL are used to access all but global variables; the "L" is for "local." They each take two arguments: the difference in lexical levels between the variable and the accessing routine and the offset of the variable. Each follows the chain of static pointers a number of times equal to the difference in lexical levels and then uses the offset to access the variable. PUSHL pushes the value of the variable onto the stack; POPL pops the top of the stack into the variable.

(continued)

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Two instructions, RETURN and FRETURN, handle returns. Both take one argument, the number of words of actual parameters (arguments) pushed onto the stack by the caller. They need this value to determine where to set the stack pointer. RETURN merely sets the stack pointer to where it was before the call, effectively popping the activation record off the stack. FRETURN (function return) first pops the top of the stack, which should contain the value to be returned by the function, then resets the stack pointer as with RETURN, and finally pushes the returned value back onto the stack.

To get a sense of the code generated by my compiler, you may want to look at listings 1b and 2b; they show the compiler's output for listings 1a and 2a, respectively.

Compiler Issues

Paradoxically, I have spent nearly all the second part of the compiler project describing a mechanism that is implemented in VM2. Of course, the mechanism would have been unnecessary were it not for the peculiar problems that arise in compiling high-level languages with nested procedures and functions. But it is now time to move to the compiler proper.

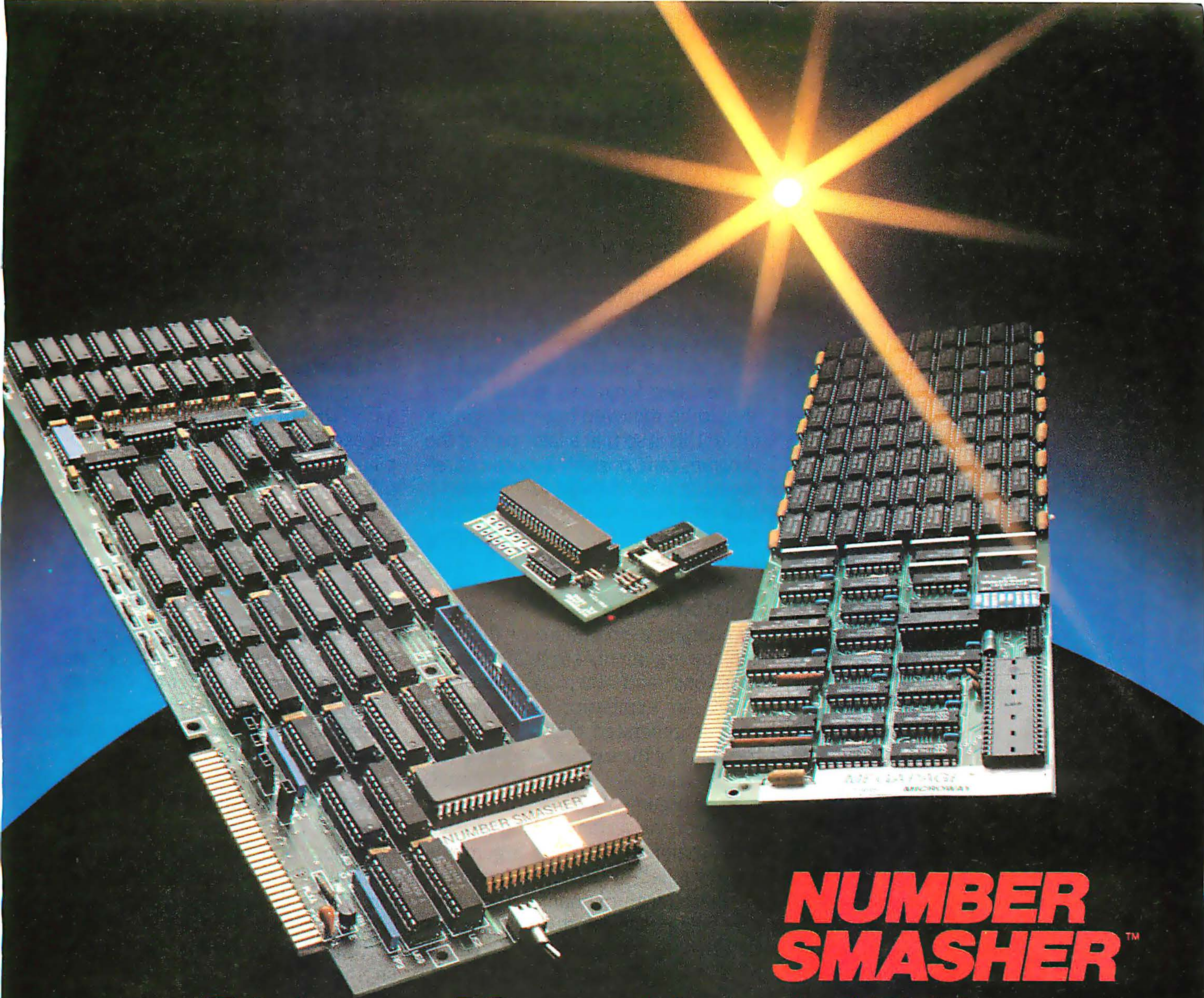
The basic action of the compiler when it sees a routine is as follows: First, the routine name is entered into the symbol table. Then, the list of formal parameters is parsed; each formal parameter is entered separately into the symbol table, and the whole list of formals is attached to the routine's symbol-table entry as well to aid in checking calls to make sure they supply the right number and types of arguments. If the routine is a function, its type is then parsed and placed in the routine's symbol-table entry. Next, the local variables are parsed and entered into the symbol table. The compiler's routine-compiling procedure then calls itself recursively to handle any nested routines.

Finally, the body of the routine is compiled. The compiler first outputs a label, which is the routine's name. Then, the code to place the local variables onto the stack is generated. I do this by outputting a PUSHC 0 instruction for each local; as I said earlier, it has the effects of allocating a word on the stack and initializing the variable to 0. Lastly, the code for the body is generated. In SIMPL, if no RETURN statement is executed in a procedure, that procedure returns after its last statement is executed; to handle this, the compiler needs to generate a RETURN instruction after the code for the procedure. Functions, on the other hand, have to return values explicitly. It should be an error if they don't.

A few things are needed to embellish this basic compiling process. First, the compiler needs to remember the lexical level at which each identifier in the program is defined. It does this by means of a counter, lexicalLevel, which starts at 0, is incremented whenever a routine definition occurs, and is decremented when the compiler has finished compiling a routine. Each time a routine name or variable is defined, the current lexical level is stored with it in its symbol-table record. In order to get the visibility of routine names right, the counter must be incremented just after the routine name is seen but just before the formals are. Formals are treated as being local to the routine in which they occur.

Second, formals and locals need to be given offsets from the FP. If you take a look at the form of an activation record in figure 2, you'll see that the first local variable is one word below where the FP points to, so it should be given an offset of -1. The second local should be given an offset of -2, and so on. Things are a bit more tricky with formals, however. The compiler handles the arguments in a routine call from left to right, pushing the first argument onto the stack first. Hence, the first argument will be farthest from the FP, so it should have the highest offset. To assign offsets to formals, the compiler must read them all in first, count how many there are, then go back through them and assign the offsets. Because

(continued)



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of the way I've set up the activation record, the last argument—the one closest to where the FP points—will have an offset of 3.

One final consideration is that after the compiler is done with a routine, all identifiers local only to that routine should be removed from the symbol table. This is so that a later part of the program can't possibly succeed in referencing one of these identifiers. I'll now describe how to compile the various constructs that arise in dealing with routines.

Routine Calls

To compile a procedure or function call, the arguments are treated as expressions and each is compiled. When an expression is compiled, code is generated that will result in the value of the expression being left on the stack at run time, so compiling the arguments as expressions is just what the routine-calling mechanism requires. After the arguments are compiled, a CALL instruction is generated with the name of the routine being called and the difference between the lexical level of the called routine and the current lexical level. The compiler also performs several checks: The called routine must be a function if the call occurs in an expression, otherwise it must be a procedure; and the number of arguments and their types must match with the list of formal parameters.

SIMPL RETURN Statement

When the compiler sees a RETURN statement followed by an expression, it checks to make sure it is in the process of compiling a function; if so, it generates code for the expression (which will result in the expression's value being pushed onto the stack at run time) and generates an FRETURN instruction. When the compiler sees a RETURN statement with no following expression, it makes sure it is compiling a procedure, then it generates a VM2 RETURN instruction.

Variable Access

When a variable is used in the code, the compiler looks it up in the symbol table. If it is global, its name is used. If not, a PUSHL or POPL instruction is generated, as appropriate, with the variable's offset and the difference in lexical levels between the current one and the one in which the variable was defined.

Name Management

Two minor problems remain for the compiler, both having to do with managing the names of identifiers. The first one concerns routine name clashes. Say you have two routines, P and Q. Inside P you can define another routine, R, and inside Q you can also define a routine called R. The problem is that you can't use the routine names as labels in the assembly-language program, since then you would have two "R" labels, and that's illegal in my assembler. The easiest solution is to generate a new label for every routine and record the label in the routine's symbol-table entry for use when the routine is called.

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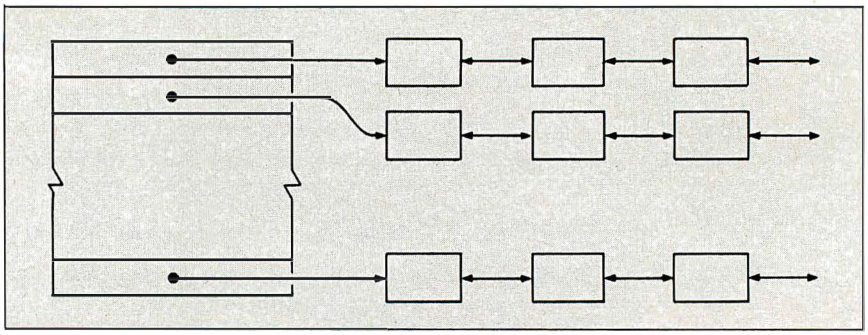


Figure 5: *The structure of the symbol table: an array of pointers to doubly linked lists of symbol-table entries.*

The second problem concerns the process of looking up an identifier in the symbol table. Recall that the second scoping rule states that when an identifier that is declared in a nested routine is also declared inside the routine in which it is nested, the innermost identifier shadows the other. So the *b* referred to by procedure R in listing 2a is the variable local to R, not the ones local to Q or P. How can we implement the identifier lookup routine so that this scoping rule is enforced?

The obvious solution is to examine all the identifiers with the same name and choose the one defined at the highest lexical level. This solution will work, but a simpler one suggests itself if you notice that identifiers in lower lexical levels are declared before those in higher ones. That is, as the compiler reads the program from top to bottom, it will first install global variables into the symbol table, then variables at lexical level 1, and so on. If the symbol table were merely a list of entries, and if new entries were inserted at the beginning of the list, the lookup routine could simply take the first identifier whose name matched the one being looked up; since that identifier was the most recently inserted of all those with the same name, it must have been defined at the highest lexical level.

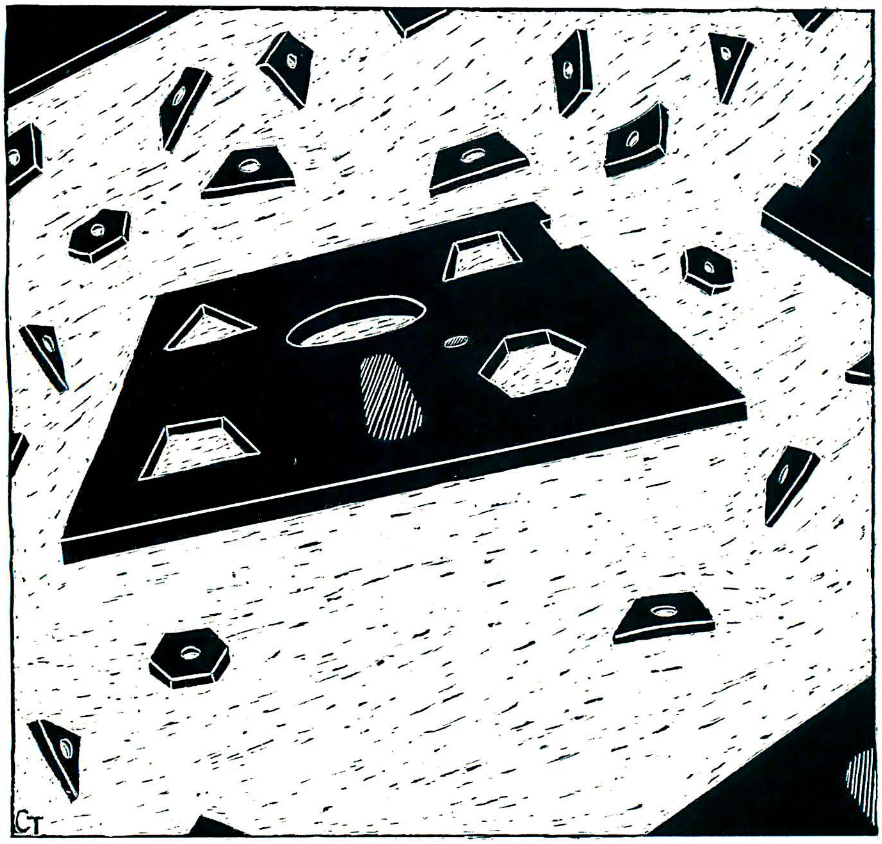
In practice, though, a single list is too inefficient a representation for a symbol table—the lookup time is proportional to the length of the list, and if there are many identifiers, the list will be long. It would be great if the symbol table could combine the efficiency of a hash table with the nice lookup property of a list. That's possible if each element of the hash table, instead of containing a single symbol entry, contains a pointer to a list of entries. Instead of one long list, the symbol table consists of an array of shorter lists; and since identical strings hash to the same location in the array, all the identifiers with the same name will be on the same list. The lookup routine hashes the name of the identifier it is searching for, indexes the array to find the appropriate list, and searches the list in order, taking the first match it finds. To facilitate the removal of entries, the list is doubly linked. The structure of the symbol table is illustrated in figure 5.

CONCLUSION

The Modula-2 source code for my SIMPL compiler, including the code to handle routines, along with the VM2 assembler and VM2 monitor, are available for downloading from BYTEnet Listings. The telephone number is (617) 861-9764. In part 3 next month, I'll extend the compiler by adding some useful features like arrays. ■

BY NAMIR CLEMENT SHAMMAS

CREATING REUSABLE MODULES



Capsule editors quickly customize modules in Modula-2

The advent of Modula-2 marked another step in the evolution of structured programming languages. Modula-2 evolved from Pascal and addresses some programming aspects more effectively than its predecessor. Most important is its ability to create separate modules that are procedure libraries. These libraries perform many related tasks. The concept of modules stresses the ability to tackle a big software project and apply (reuse) the same code in future programs. This cuts down on software development time, cost, and debugging. This article discusses module reusability—its limitations and remedies.

To reuse code, you must write procedures and modules that have some degree of freedom from the rest of the program. These modules carry out specific tasks while interchanging data with other parts of the program via global variables, call arguments, and data files. Modula-2, however, imposes some restrictions to prevent this freedom from turning chaotic.

Modula-2 requires that any variables passed to procedures be of the exact same *type* (i.e., you can't mix apples and oranges), and it allows no generic types. The language relaxes this somewhat for procedure calls for arrays. You can declare an open array without specifying its bound limits, which means that procedures can accept arrays of different sizes but not of different basic types. For example, you can have a procedure like this:

```
PROCEDURE SendString
(Name : ARRAY OF CHAR);
```

Notice that the variable Name is a character array whose dimensions are determined when the program calls the procedure SendString. Thus,

(continued)

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ILLUSTRATED BY CLAUDIA TANTILLO

SendString can accept arrays of any size as long as they have the basic type CHAR and are one-dimensional. Hopefully, future language updates will expand the open-array feature. By comparison, the Ada language allows generic types but has stricter type checking. The C language, on the other hand, shows little or no type checking and allows the programmer a great deal of freedom—and responsibility.

Remedies for some of these limitations are available in the following programming strategy:

1. Write an incomplete program skeleton that constitutes the major portion of a procedure, function, or module. This *capsule* should include as much general code as possible.
2. Write another program, a *capsule editor*, that customizes the capsule and adds the last details by interacting with the user for the required information.

The resulting code produced by the capsule editor is correct and complete.

```
Enter the output filename ? c:sort1.tst
Enter new procedure name ? ZipSort
Enter record type name ? Mail
Is the sort based on one field ? Yes
Enter fieldname ? ZipCode
```

Figure 1: *The display from running* EditSort *for a single sort key.*

```
Enter the output filename ? c:sort2.tst
Enter new procedure name ? MailSort
Enter record type name ? Mail
Is the sort based on one field ? No
Enter number of fields used ? 3
Enter name for subkey # 1 ? ZipCode
Enter name for subkey # 2 ? State
Enter name for subkey # 3 ? Name
```

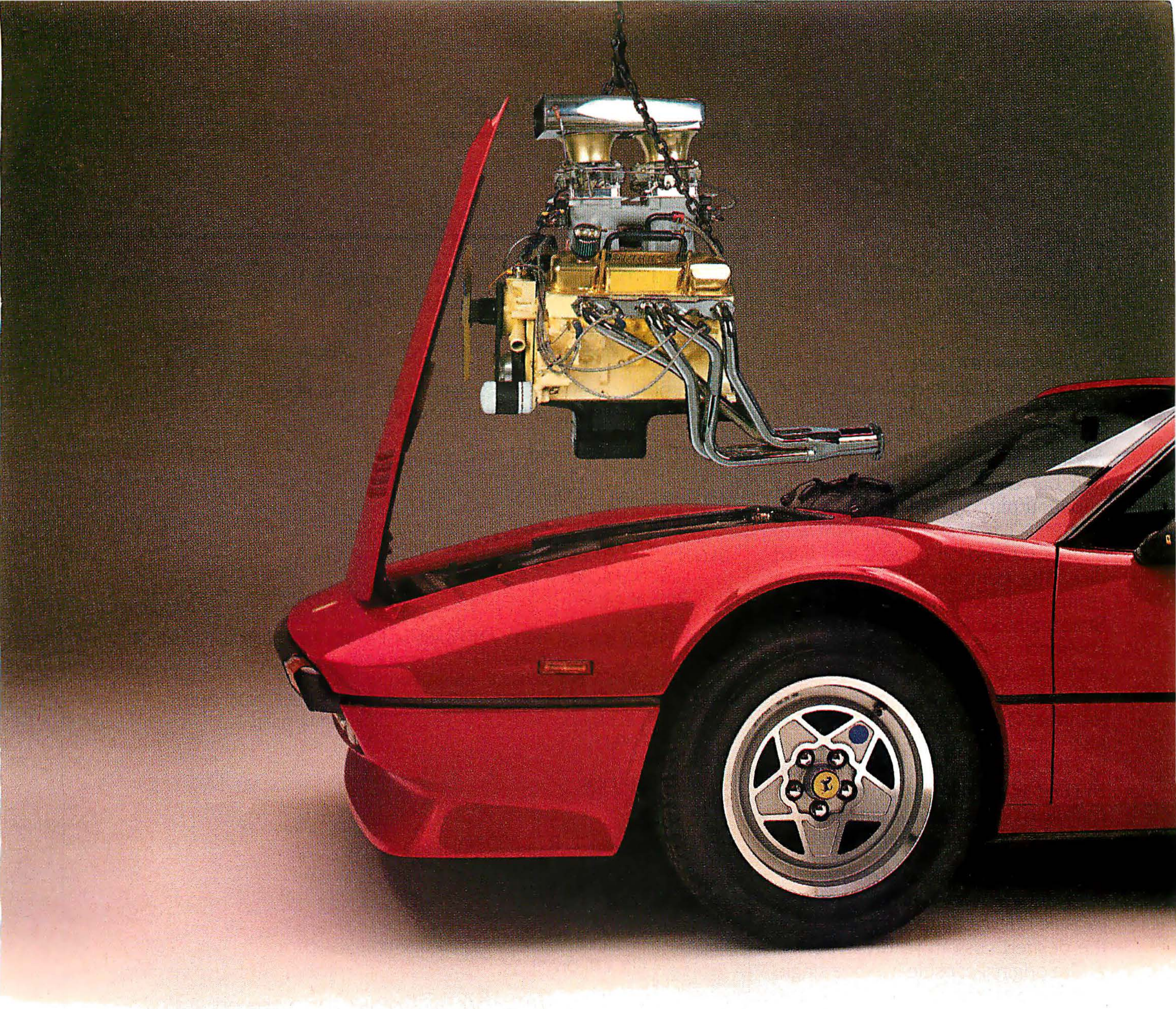
Figure 2: *The display from running* EditSort *for multiple sort keys.*

Capsule editors are entire programs that perform text editing, insertion, and addition on the code in the capsules. You can think of them as advanced processors that offer flexibility *before* you invoke the compiler. It is normal to have one capsule altered by one editor. However, you can have several capsule editors work on the same capsule (or the reverse), and you need not write the capsules and their editors in the same language.

The advantages of using capsule editors are

- easier and faster means of producing custom programs
- lower software development cost

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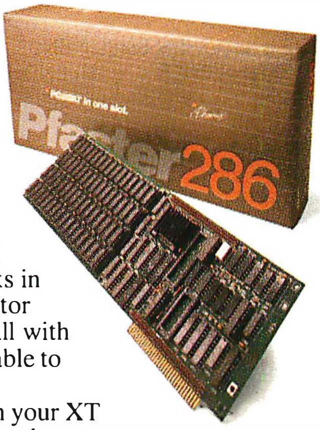


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A Demonstration

This demonstration deals with a sort algorithm. I used Logitech's Modula-2/86 compiler, version 0.3c, which does not have floating-point implementation but does have reliable file I/O (input/output) operations. I used an IBM PC XT to test the program with all files located on drive C, the hard disk. The compiler did not have a string-manipulation library so I used Strlib1, a module I developed earlier. Reference 1 contains the code for this entire module.

The example is a capsule for the recursive QuickSort algorithm. [*Editor's note: Listings for* QUIKSORT.MD2 *and* EDITSORT.MD2 *can be downloaded from* BYTE*net listings at* (617) 861-9764.] This capsule is a procedure written with the following assumptions and remarks:

1. The data records to be sorted are of a dummy type called Item. The capsule editor changes this to match the desired custom record type.
2. The original capsule has one single dummy sort called key, which the capsule editor alters according to your input.
3. You can only sort on alphanumeric data fields (keys).
4. If you use a field as a sort key, you must use the entire field.

The capsule editor for the QuickSort capsule is the module EditSort. It performs the following functions:

- prompts for the output filename
- prompts for the output procedure name
- asks for the record type name that you intend to use throughout your program, and
- asks for the sort keys. (Based on the number of keys involved, the capsule editor decides how to edit QuickSort. The following two cases explain how this works.)

If you want to sort a mailing list, you could call your record type, Mail, and

(continued)

Listing 1: *The output code generated by running the* EditSort *capsule editor on the* QuickSort *capsule with a single sort key.*

```
PROCEDURE ZipSort( A : ARRAY OF Mail ; N : CARDINAL );

PROCEDURE Compare ( S1, S2 : ARRAY OF CHAR): BOOLEAN;
(* Compare two strings of the same maximum length. *)

CONST eos = 0C; (* end of string *)

VAR Less, Stop : BOOLEAN;
    i : CARDINAL;

BEGIN
    Less := FALSE;
    Stop := FALSE;
    i := 0;
    WHILE (i <= HIGH(S1)) AND (Less = FALSE) AND (Stop = FALSE) DO
        IF (S1[i] <> eos) AND (S2[i] <> eos)
          THEN (* Proceed in comparison *)
              IF (S1[i] < S2[i]) THEN Less := TRUE ELSE INC(i) END;
          ELSE Stop := TRUE (* Reached the end of string*)
        END;
    END;
    RETURN Less;
END Compare;

PROCEDURE Sort( L, R : CARDINAL);

VAR i, j : CARDINAL;
    X, W : Mail;

BEGIN
    X := A[(L+R) DIV 2];
    REPEAT
        WHILE Compare(A[i].ZipCode,X.ZipCode) DO INC(i) END;
        WHILE Compare(X.ZipCode,A[i].ZipCode) DO DEC(j) END;
        IF i <= j THEN
            W = A[i] := A[i] ; A[i] := A[j] ; A[j] := W ;
            INC(i) ; DEC(j)
        END;
    UNTIL i > j ;
    IF L < j THEN Sort(L,j) END;
    IF i < R THEN Sort(i,R) END;
END Sort;

BEGIN

    Sort(1,N)

END ZipSort;
```

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Listing 2: *The output code generated by running the* EditSort *capsule editor on the* QuickSort *capsule with multiple sort keys.*

```
PROCEDURE MailSort( A : ARRAY OF Mail ; N : CARDINAL );

PROCEDURE Compare ( R1, R2 : Mail): BOOLEAN;
(* Compare two strings of the same maximum lengths.*)

CONST eos = 0C; (* end of string *)

VAR Less, Stop : BOOLEAN;
    i : CARDINAL;
    S1, S2 : ARRAY [1..YourMaxString] OF CHAR;

BEGIN
    Less := FALSE;
    Stop := FALSE;
    i := 0;
    StringIs(S1,R1.ZipCode) ; StringIs(S2,R2.ZipCode) ;
    StringAdd(S1,R1.State) ; StringAdd(S2,R2.State) ;
    StringAdd(S1,R1.Name) ; StringAdd(S2,R2.Name) ;
    WHILE (i <= HIGH(S1)) AND (Less = FALSE) AND (Stop = FALSE) DO
        IF (S1[i] <> eos) AND (S2[i] <> eos)
          THEN (* Proceed in comparison *)
            IF (S1[i] < S2[i]) THEN Less := TRUE ELSE INC(i) END;
          ELSE Stop := TRUE (* Reached the end of string*)
        END;
    END;
    RETURN Less;
END Compare;

PROCEDURE Sort( L, R : CARDINAL);

VAR i, j : CARDINAL;
    X, W : Mail;

BEGIN
    X := A[(L+R) DIV 2];
    REPEAT
        WHILE Compare(A[i],X) DO INC(i) END;
        WHILE Compare(X,A[i]) DO DEC(j) END;
        IF i <= j THEN
          W = A[i] := A[i] ; A[i] := A[j] ; A[j] := W ;
          INC(i) ; DEC(j)
        END;
    UNTIL i > j ;
    IF L < j THEN Sort(L,j) END;
    IF i < R THEN Sort(i,R) END;
END Sort;

BEGIN

    Sort(1,N)

END MailSort;
```

declare it as

```
TYPE Mail = RECORD
    Name : ARRAY [1..30] OF CHAR;
 Address : ARRAY [1..30] OF CHAR;
    City : ARRAY [1..20] OF CHAR;
   State : ARRAY [1..2] OF CHAR;
 ZipCode : ARRAY [1..9] OF CHAR
END;
```

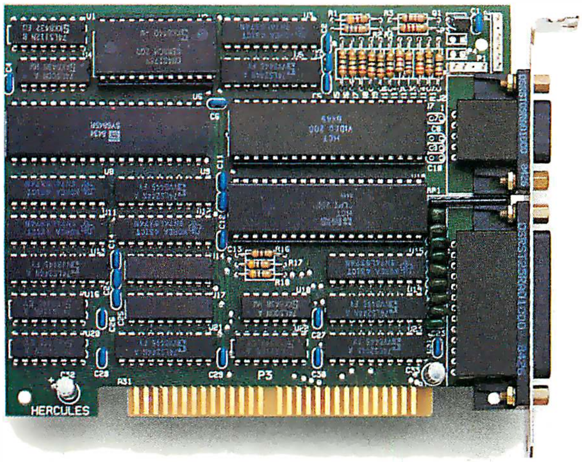
In the first case, you want to sort by zip code only. Create a new procedure named ZipSort, and store it in file c:sort1.tst. Figure 1 shows the display for this case and listing 1 shows the output file. If you compare it with the original capsule, you will see that the capsule editor alters only the procedure name, the record type name, and the sort key according to your input. *It adds no program lines!*

In the second case, you want to sort by three fields (zip code, state, and name). Call the new procedure MailSort, and save it in file c:sort2.tst. Figure 2 shows the display and listing 2 shows the output file. In this case, the action exceeds mere renaming. The capsule editor alters the argument calls of the procedure Compare; it takes records of type Mail instead of strings as arguments; it declares strings previously passed as local variables; and it adds enough code lines to build the sort strings. The capsule editor even alters the use of Compare in the procedure Sort, and it eliminates dummy key components altogether.

The strategy of using capsules provides you with a new kind of software tool. When applied to supercomputers, these tools create a new class of programmers. Modula-2 capsules offer an alternative to changing the code prior to compilation, one that allows modules to be quickly customized. ■

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3. Wirth, N., *Algorithms + Data Structures = Programs*. Englewood Cliffs, NJ: Prentice-Hall, 1976.



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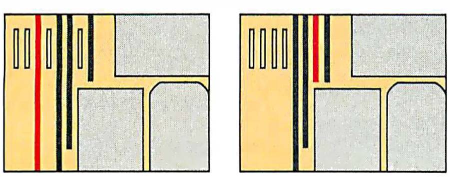
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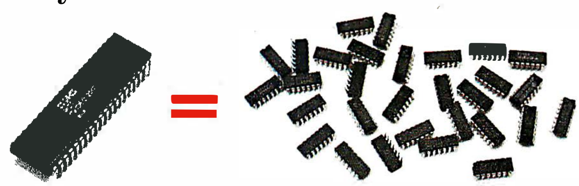


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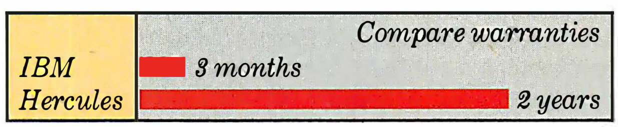
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EASY 3-D GRAPHICS

BY HENNING MITTELBACH

A BASIC program for plotting 3-D surfaces

AFTER READING "Budget 3-D Graphics" by Tom Clune (March 1985 BYTE, page 240), I decided to develop a low-cost program for three-dimensional graphics on small computers. [*Editor's note: Versions of the program for the IBM PC, Macintosh, and Apple II/IIe are available for downloading via BYTEnet Listings. The telephone number is (617) 861-9764. More information on downloading to your particular machine can be found at the end of the article.*]

The program is based upon the formulas for an axonometric projection in relation to the origin, as shown:

XB = X*COS(PHI) – Y*COS(PSI)
YB = X*SIN(PHI) – Y*SIN(PSI) + Z

Depending on the graphic window of the computer used, you may change these formulas to

XB = X0 + X*COS(PHI) – Y*COS(PSI)
YB = Y0 – X*SIN(PHI) – Y*SIN(PSI) – Z

where X0 and Y0 will represent the origin of the axes, as shown in figure 1. (I developed the program on an Apple II, with X0 = 110 and Y0 = 180.) Also in figure 1, (XB,YB) is the point to be plotted, and PHI and PSI are the angles referring to the horizon. The function Z = F(X,Y), in line 200 of the program, needs a scaling factor F (line 210) that the user has to introduce in the program.

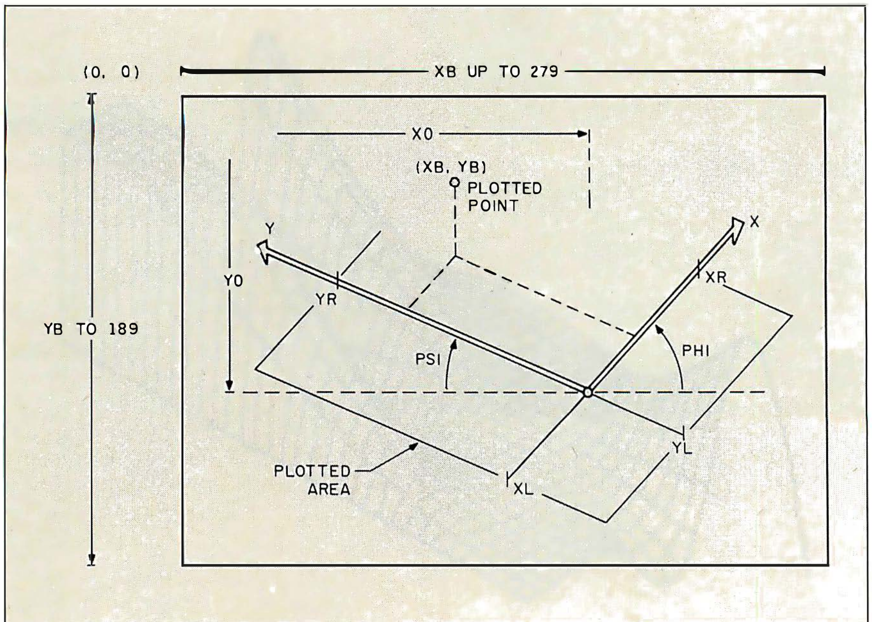


Figure 1: *The graphic window, shown here for the Apple II, on which the 3-D graphics program was developed.*

THE PROGRAM

The program starts at lines 100 to 180 where you set the parameters X0, Y0,

(continued)

Henning Mittelbach (FH München, Lothstrasse, D8000 München, West Germany) is professor of mathematics at Fachhochschule München.

PHI, PSI, XL, XR, YL, YR, and D. Changing parameters gives you variety. It is important that XL be less than XR and YL be less than YR, though these values may be either positive or negative.

The parameter D gives the distance between the coordinate lines to be plotted. The program sets D = 5, although you can make D smaller (for a more detailed graph) or larger (for a coarser graph that takes less time to plot). You should be sure, however, that the differences XR – XL and YR – YL are multiples of D, or the graphic will have no contour.

Line 200 contains the function to be plotted. Figure 2, for example, shows the plot of the program with the function

FN Y(X) = SIN (Y/F) * (X – Y) * (X – Y)/150

The parameter F, in line 210, stretches the X and Y directions in the argument of Y(X), as does the divisor 150 in line 200.

After fitting some abbreviations to accelerate the plotting (which can take several minutes), line 260 sets an upper limit for FN(X). Later, in lines 1040 and 2040, the program cuts those values of F(X) that would fall above the top of the window.

Line 270 asks whether you want to see the graph with two sets of coordinate lines, as in figure 2, or with one set of coordinate lines (which takes less time). Depending on your response, the program goes to subroutines at line 1000 or 2000.

Lines 300 to 330 ask if you wish to see the axes or not, and will draw them if you do, while line 350 draws a frame for the graph.

Next, an array H is set to the lower border of the window. Later, a part of this array will be plotted to get the hidden lines.

The program continues with line 1000. First the mask (array H) is raised to the front line of X. Later, the Y-coordinate lines can only be plotted if they are above this border. Thus, in line 1060

IF YB < H(XB) THEN H(XB) = YB

a small value for XB will be corrected up.

Line 1120 starts the first Y-coordinate line with the smallest Y value, Y = YL. The inner loop Y com-

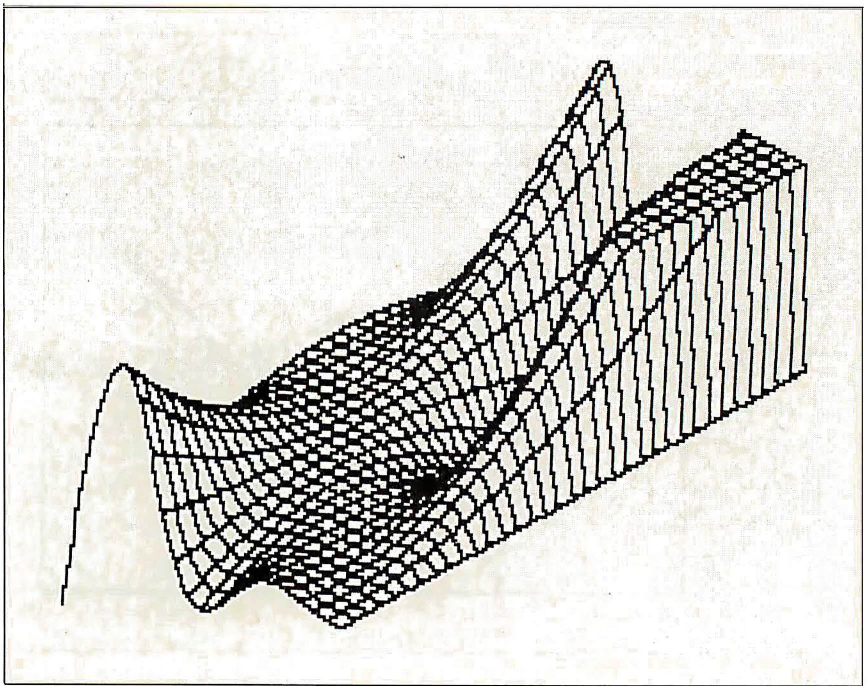


Figure 2: *The 3-D plot of the function* FN Y(X) = SIN(Y/F)*(X – Y)*(X – Y)/150.

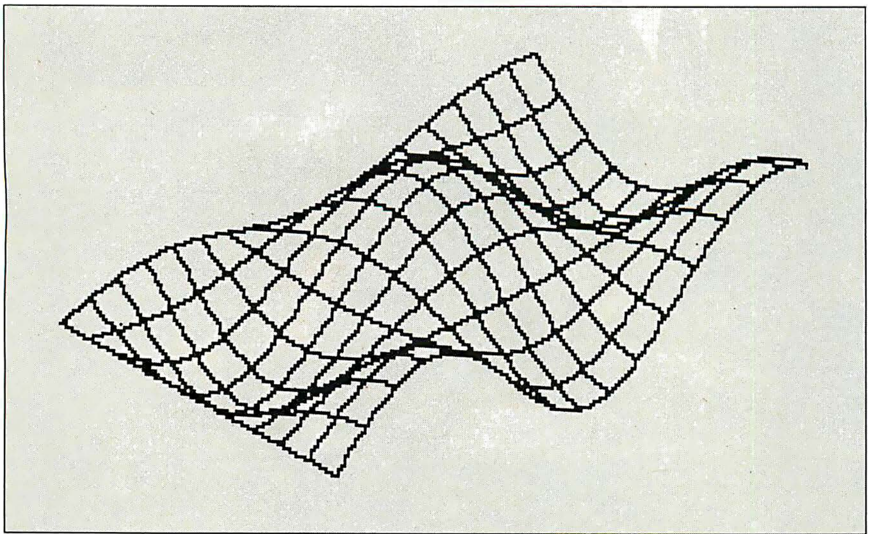


Figure 3: *The 3-D plot of the function* FN Y(X) = 20*SIN(X/F)*COS(Y/F).

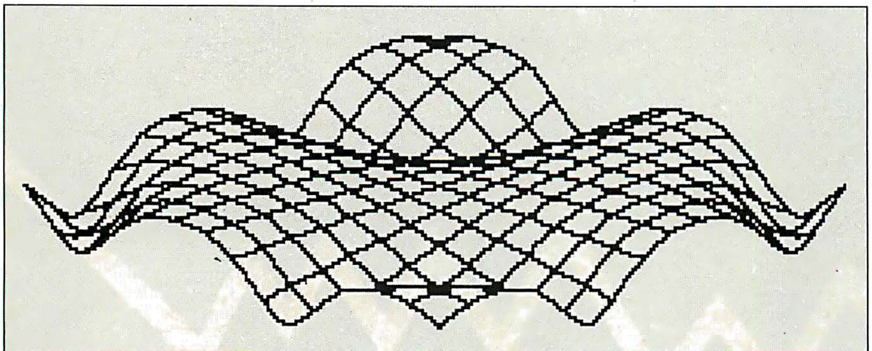


Figure 4: *The 3-D plot of the function* FN Y(X) = −8*EXP(SIN(X*Y/F/F)).

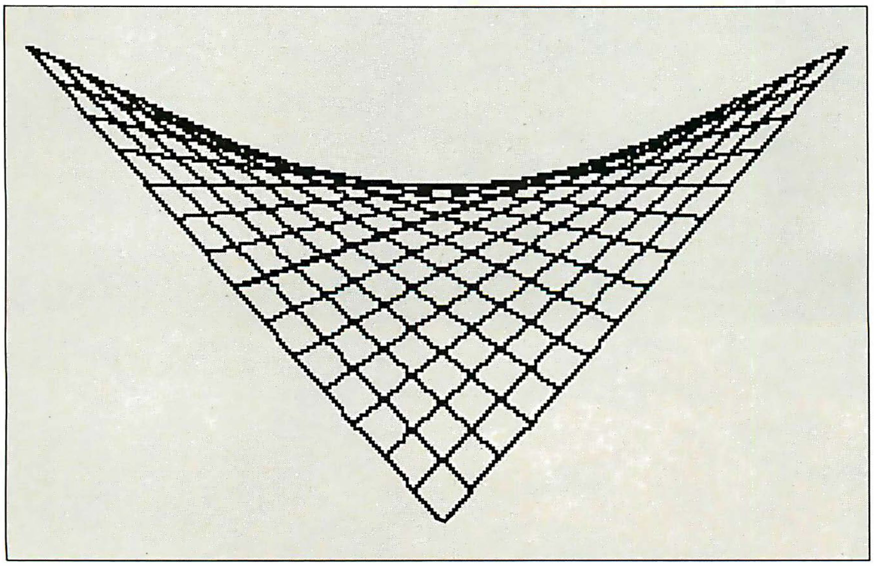


Figure 5: *The 3-D plot of the function* FN Y(X) = −X*Y/F/F.

putes all points with fixed X (first X=XL) and then, after setting the mask on this line, plots the line (lines 1200 to 1220 of the program).

Lines 2000 to 2240 are an exact copy of lines 1000 to 1240 and are called if you choose the cross-hatching option at the beginning of the program run.

A number of examples follow. Figure 2, the 3-D graphic that comes with the program, uses the parameters

XO = 110
YO = 180
PHI = 0.5
PSI = 0.4
XL = 0
YL = 0
XR = 170
YR = 100
D = 5
FN Y(X) = SIN (Y/F) * (X − Y) * (X − Y)/150
F = 10

Figure 3 uses similar parameters, except that D = 10, F = 20 and the function

FN Y(X) = 20 * SIN(X/F) * COS (Y/F)

was substituted on line 200. The parameters

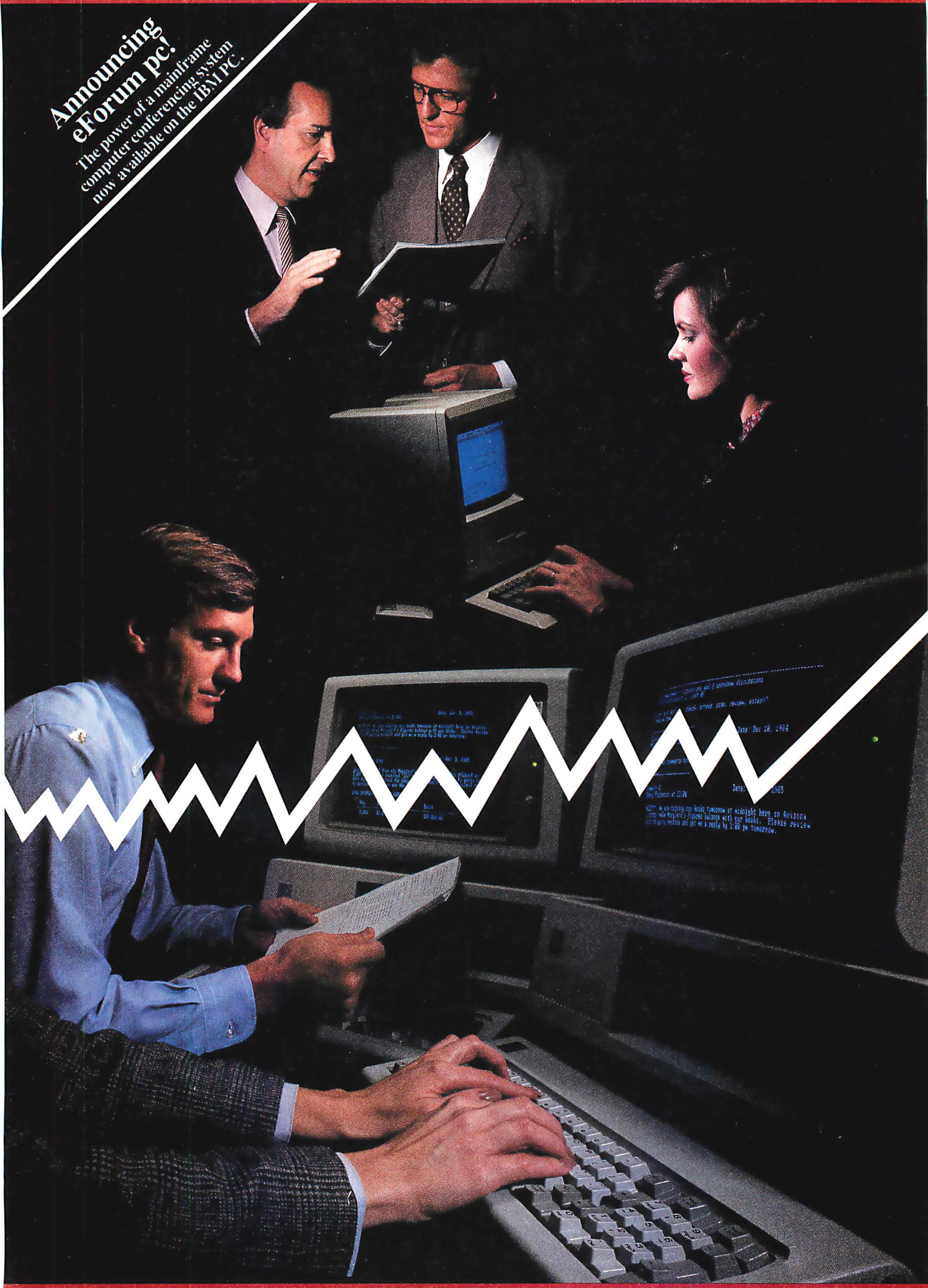
XO = 140
YO = 100
PHI = 0.3
PSI = 0.3
XL = −70
YL = −70
XR = 70
YR = 70
D = 10
FN Y(X) = −8 * EXP (SIN(X*Y/F/F))
F = 28

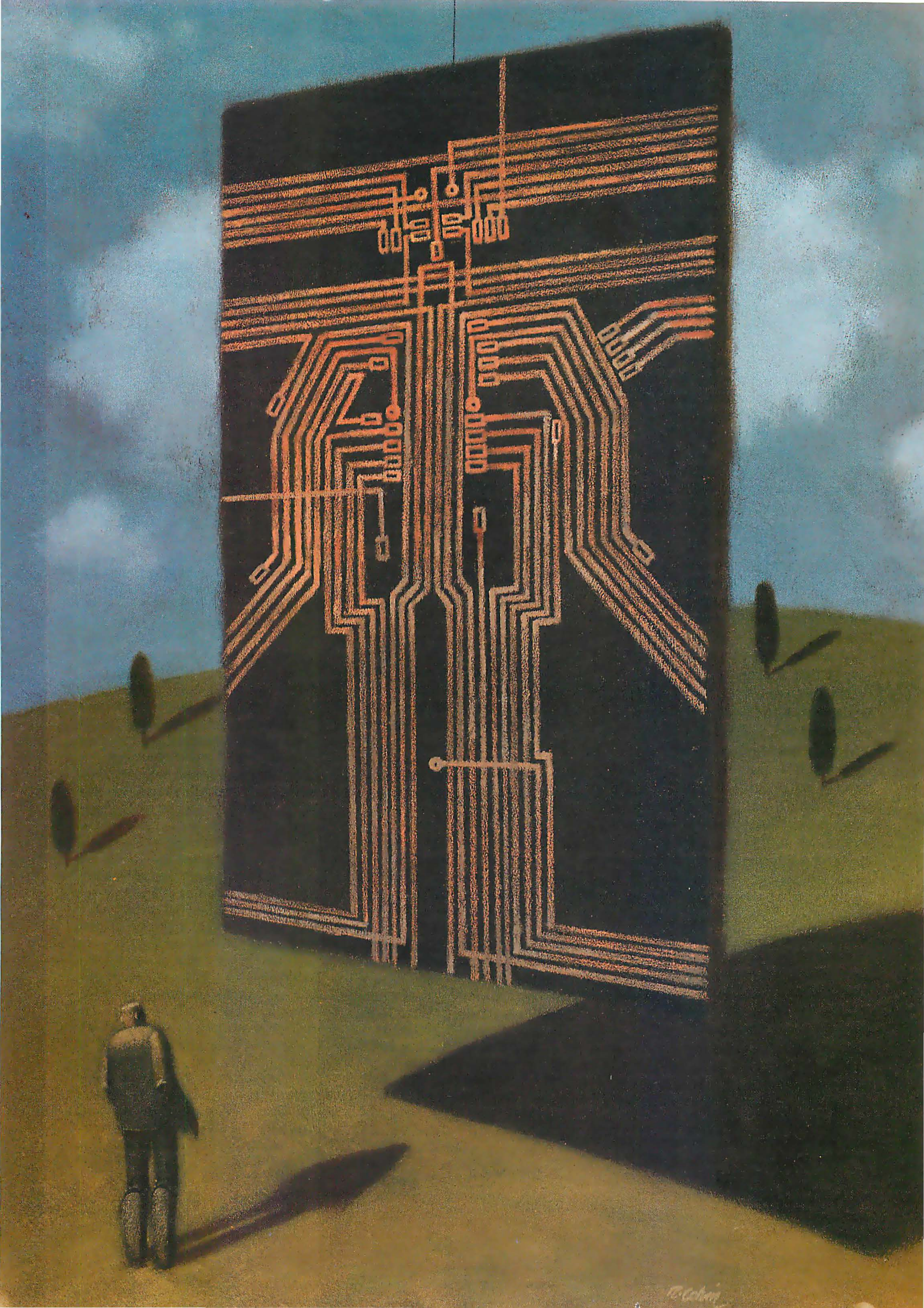
produce figure 4. Changing the function on line 200 to

FN Y(X) = −X*Y/F/F

and setting F = 10 produces the plot shown in figure 5. ■

The program for easy 3-D graphics is available as PCGRAF.BAS *for the* IBM *Personal Computer,* MACGRAF.BAS *for the Apple Macintosh, and* APPLGRAF.BAS *for the Apple* II *family* (DOS 3.3). *You will need* BASIC *for whichever system you choose.*


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Robotics

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I TEND TO THINK of servo- and stepper-motor control, data acquisition with sensors, and the like as mature technologies. So when I began to research this theme, the foremost questions in my mind were, What makes robotics so hard? Why is it taking so long to develop this technology? This month's theme authors provide clear explanations of what some of the major problems are and indicate some of the new research developments that are finally bringing robotics to maturity.

One set of robotics problems involves sensors. We begin our theme with two pieces on this topic, one on vision and the other on touch. It is generally agreed that these two are necessary (and possibly sufficient) for most autonomous robotic functions.

First, Phil Dunbar presents a discussion of the problems of current camera systems for robotic vision. He includes an overview of some of the more interesting cameras available for machine vision.

Next, Kirk Pennywitt looks at directions in research on touch sensors. Those who think of mechanical touch as synonymous with pressure transducers will be surprised to learn how complex this subject really is.

Motion is central to the idea of robotics. We have two pieces that discuss some of the issues associated with machine motion. J. Scott Hawker, R. N. Nagel, Richard Roberts, and Nicholas G. Odrey discuss coordination of two arms in performing a task. Research on this topic is just beginning, so the focus of the piece is more on problems to be addressed than answers that have been devised. Charles Jorgensen, William Hamel, and Charles Weisbin consider the levels of complexity of robotic navigation. They use a delightful analogy to Magellan, Columbus, and Ulysses to clarify the issues involved in machine exploration.

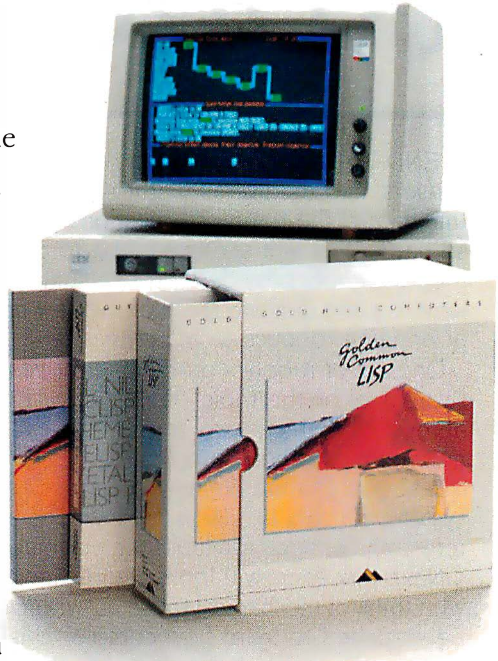
The problems of robotic navigation are primarily concerned with artificial intelligence, as is our next piece. Clara and John Cuadrado discuss artificial intelligence in machine vision. Their article explains such AI concepts as frames, inheritance, and demons so clearly that I finally understand what these terms mean.

Finally, Gary W. Kramer and Philip L. Fuchs discuss how they used a robotic arm to automate their organic chemistry laboratory. I find two aspects of their piece especially interesting. First is how they solved the universal problem in robotics of interfacing disparate equipment. Second, the arm that they employ is perhaps the lowest-tech piece of equipment in their lab, but it has allowed them to unlock the power of the intelligent instruments with which they work.

It is impossible to cover all the major topics of robotics in a single theme. For example, both Phil Dunbar and the Cuadrados acknowledge that the hardest part of machine vision is the intermediate level, where camera data is analyzed to identify, for example, two overlapping objects in a field of vision. This is a hot topic in current vision research but is not included in our theme. However, we found the articles that are here exciting and informative. We hope you have as much fun reading them as we did.

—Tom Clune, Technical Editor

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MACHINE VISION

BY PHIL DUNBAR

An examination of what's new in vision hardware

THE POTENTIAL APPLICATIONS of machine vision are many and obvious. Everything from quality assurance to robotic navigation could benefit from the availability of reliable vision systems for computers. Perhaps less obvious, though, is the variety of problems that hamper development of the technology. These problems appear on all levels of machine vision—hardware, low-level analysis, and high-level AI (artificial intelligence) manipulation of low-level data. This article will discuss problems that plague the development of vision-system hardware and indicate some of the technology that has emerged to address these problems.

You might think that the most difficult hardware problem in vision systems is digitizing the high-frequency analog stream of camera data. In fact, that is not so. Currently, machine vision algorithms use gray-scale (i.e., monochrome intensity) video information almost exclusively. Such information can be adequately extracted from an analog signal by a 6-bit or 8-bit A/D (analog to digital) converter. Real-time conversion requires approximately a 10-MHz conversion rate to digitize a 512- by 512-pixel image. These rates can be achieved with flash converters, pioneered by the TRW company when it introduced the TDC 1007 in 1977. Flash converters employ $(2^N)-1$ comparators to perform N-bit conversions. That is, an 8-bit flash comparator requires 255 comparators to operate. Since all possible digitized values can be compared to the signal at once, the throughput is much greater than with successive approximation methods. Of course, the complexity of the converter rises exponentially with linear increases in resolution. Notable among the commercially available flash converters is TRW's 8-bit monolithic chip flash converter (TDC 1048) that can operate at speeds necessary for real-time machine vision applications and costs about $140 per unit.

The real problems with vision hardware revolve around the cameras. The problems fall into two basic categories: video signal standards and limitations of particular camera hardware technologies.

TELEVISION STANDARDS

Much of robotics suffers from a lack of standards. Machine vision, on the other hand, suffers from the existence of video signal standards that are not appropriate for our needs. Those standards were created by and for the television industry. Since the entertainment industry is still a far more lucrative market for camera manufacturers than machine vision, few image sensors and cameras deviate from television standards.

The monochrome video signal standard used in the United States, Japan, and most of the Western Hemisphere is RS-170, a subset of the NTSC (National Television Systems Committee) standard. Europe uses the international CCIR (Consultative Committee, International Radio) standard, which is similar to, but not compatible with, RS-170. Since both standards present essentially the same problems to machine vision applications, I will limit my remarks to the RS-170 standard.

The RS-170 standard defines the composite video and synchronizing signal that your television uses (see figure 1). The image is transmitted one line at a time from top to bottom of

(continued)

Phil Dunbar is Manager of Software Engineering, Industrial Automation Division, Analog Devices Inc. (POB 280, *Norwood,* MA 02062).

the television screen. The full image frame consists of 525 lines, repeated at 30 Hz. Each frame consists of two interleaved fields of 262.5 lines. Forty lines are blank to allow for vertical retrace of the raster scan. Sync signals precede each line of video signal. The synchronization may originate from either the camera or the display apparatus.

Unfortunately for robotics and other machine vision tasks, the RS-170 standard specifies a 4:3 horizontal-to-vertical aspect ratio for video signals. This means that the video-signal represention of a square will be longer in the *x* direction than in the *y* direction. Your television has a complementary distortion of a 3:4 aspect ratio, so the image of the square ends up appearing visually correct. However, this system poses a problem to algorithm design, since vision algorithms measure distances and tolerances by counting pixels from edge to edge. When viewed through a 4:3 aspect ratio, there is a geometric distortion. At the digital level, circles become ellipses and squares become rectangles. Thus, distance measurement is tedious for objects of random orientation. For example, to determine the length of a straight edge, you must project the edge onto the *x* and *y* axes, normalize the distance on one axis to the opposite (reference) axis, and then calculate the true length as the hypotenuse. It would help to have machine vision cameras with a symmetric aspect ratio. Some do exist, but there is no public standard for the composite output signal.

Lights, Camera, Action

There are other problems associated with the entertainment-industry bias of camera technology besides inappropriate standards. Primary among these is simply that the technology has been developed for consumption by human eyes and brains. Biological vision tends to be insensitive to absolute light intensity, slow variation in intensity, and spatial accuracy. While the human eye is well adapted to detection of local intensity gradients, global gradients cannot be perceived without high contrast. Since overengineering any product does not make economic sense, video cameras tend to suffer the same biases as humans do. I will discuss some of these biases in detail later in the article.

Another problem that can be traced to the entertainment industry is that most video cameras exhibit a nonlinear response to light intensity to compensate for nonlinearity in CRT (cathode-ray tube) monitors. What linearity means when you are talking about light intensity is not intuitively obvious, so I will pause to clarify this concept.

Camera dynamic range is determined by the ratio between video output amplitude at saturation and RMS (root mean square) noise in darkness. It is essentially limited by noise in the low end and maximum charge capacity in the high end. Some cameras have automatic gain control (AGC), which adjusts the absolute gray-scale response of the sensor to total brightness of the scene. Most often, however, you will control the illumination in machine vision applications. Thus, you may need to use reference gray values when you switch from scene to scene, or important information may be compressed in dark regions of the scene by AGC adjustment to bright regions.

Gray-scale response linearity is specified by the term gamma (γ), which is the exponent in the function $A = K * I^{\gamma}$, where I is light intensity, K is a constant, and A is the output amplitude. A gamma of 1 yields a linear response, whereas less than 1 compresses the bright end of the response curve and greater than 1 compresses the dark end (see figure 2). Many video cameras have a gamma of less than 1 to compensate for video monitors that exhibit the opposite effect.

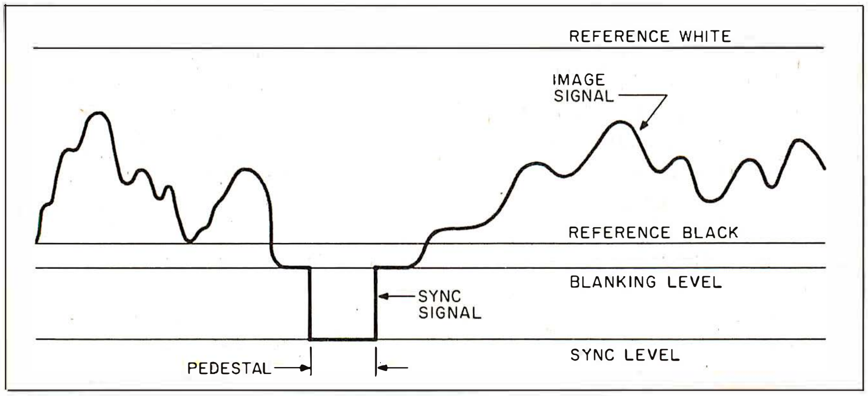


Figure 1: *A composite video signal as it might appear on an oscilloscope.*

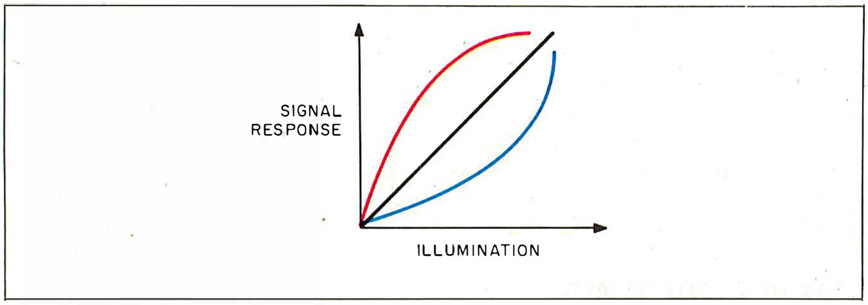


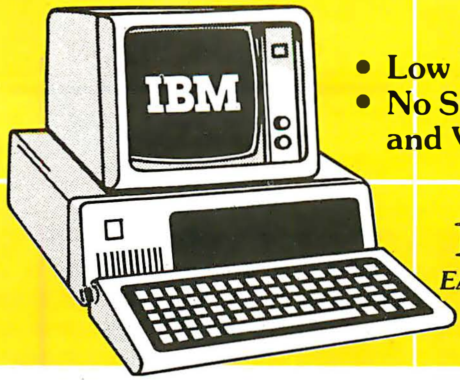
Figure 2: *A graph of response curves for* $\gamma < 1$ *(red),* $\gamma > 1$ *(blue), and* $\gamma = 1$ *(black).*

Sensor Technologies

There are essentially two types of video cameras available—one is

(continued)

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based on vacuum-tube technology, and the other is based on semiconductor technology. While tube cameras have been around for a long time, solid-state cameras date back only to the early 1970s.

VIDICONS

Since vacuum tubes have been around the longest, we will consider vacuum-tube cameras first. Various types of photoemissive devices are used for imaging in specialized applications that require low light or infrared vision. For normal video applications, the most popular and cost-effective of the tube sensors is the vidicon tube (see figure 3), a photoconductive device. It employs a photoconductive layer that develops an electric charge in response to impinging photons. An electron beam scans the photo layer in a raster format, reducing the charge along a line of the picture. This discharge produces a continuous analog signal proportional to the light intensity of the focused image. The camera electronics insert sync pulses to indicate scan lines, fields, and frame ends. Vidicons can image a wide spectral band from the ultraviolet, through the visible, to the near-infrared. As you can see in figure 4, the vidicon tube has a spectral response similar to, but broader than, the human eye.

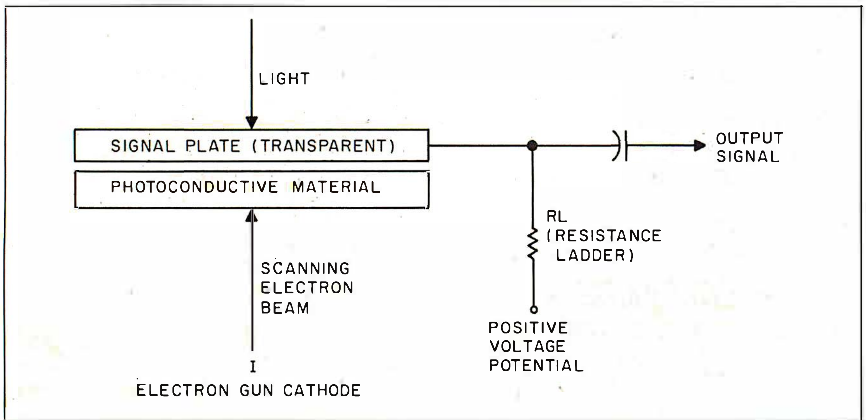


Figure 3: *A diagram of a vidicon tube sensor.*

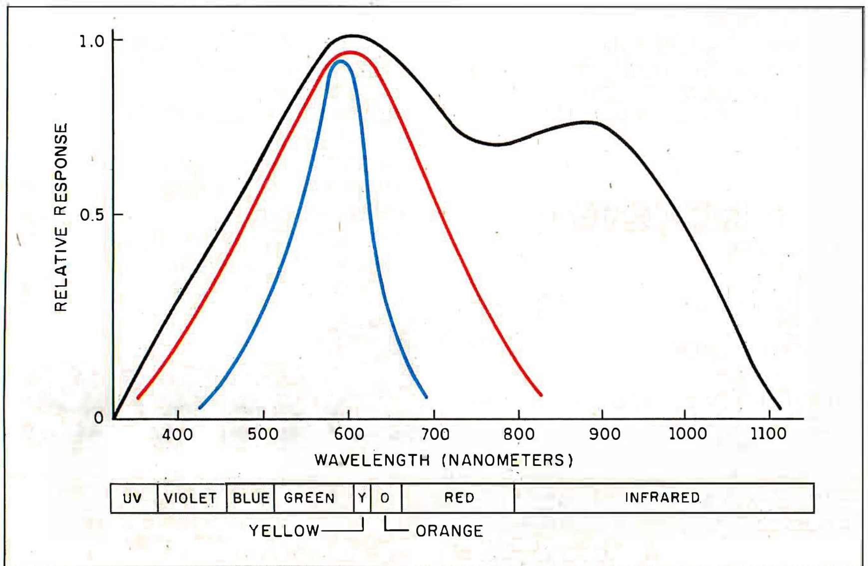


Figure 4: *The spectral response of the human eye (blue), vidicon (red), and CCD image sensors (black).*

The drawbacks to vidicon tubes are analogous to the drawbacks to tubes generally. They require more power, are less rugged, weigh more, and are larger than solid-state devices. In addition, they have one drawback that is unique to camera technology: They exhibit significant image lag. What this means is that the electric charge that was induced in the photo layer for one frame tends to persist over subsequent frames. Thus, a quickly moving bright object will appear to leave a tail in its wake, rather like a comet. A newer kind of tube sensor, called the newvicon tube, has lower image lag than the vidicon. However, the newvicon has a spectral response biased toward the far-red region.

SOLID-STATE CAMERAS

Most solid-state cameras are based on charge-coupled device (CCD) technology, which is now closing in on the performance of existing camera tubes. Silicon, with energy sensitivity in the range of 400 to 1100 nanometers (see figure 4), is a good choice for detection in the visible spectrum. However, one of the problems of solid-state image sensors is that they have a peak sensitivity in the near-infrared, although most have a bimodal spectral response with a second peak in the green. Because of broad near-infrared sensitivity between 800 and 1100 nm, you should use an infrared cut filter with solid-state cameras, particularly if they will be used under incandescent lighting. Ambient infrared light has a "wash-out" effect on response in the visible spectrum. In fact, most solid-state camera manufacturers specify sensitivity only with an infrared filter.

Solid-state sensors can be either metal-oxide semiconductor or photodiode. The basic structure of the CCD is that of an analog shift register consisting of a series of closely spaced capacitors. Charge integration by the capacitors provides the analog representation of light intensity.

CCD sensors most commonly use

(continued)

one of three addressing strategies: interline transfer, frame transfer, or column-row transfer.

INTERLINE TRANSFER

The interline transfer CCD is organized into column pairs of devices. An imaging column of photosensors is adjacent to an opaque vertical shift register (see figure 5). Charge accumulates in the imaging column until the end of the integration period, when it is transferred to the opaque column. The signal then shifts vertically into a horizontal shift register that represents the picture sequentially, line by line. Since the photosensor area is interspersed with image-insensitive shift registers, there is a grate pattern that can create undesirable interference called aliasing and moiré effects (see the glossary on page 168).

The advantage of the interline transfer is that the transfer time (to opaque storage) is short compared to the integration period. This is desirable because when transfer time approaches the integration time, solid-state sensors tend to exhibit a locally contained spreading of image response. Such spreading is called, appropriately enough, *smear*. Interline transfer minimizes smear.

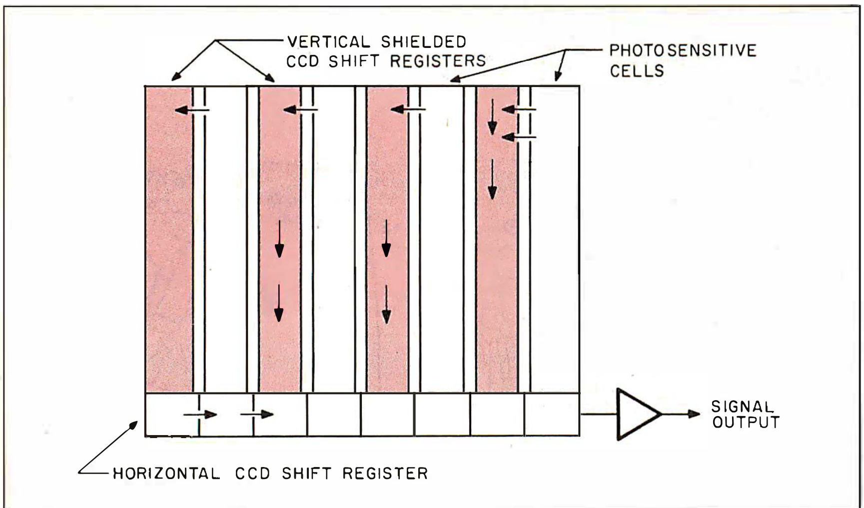


Figure 5: *A diagram of an interline transfer* CCD.

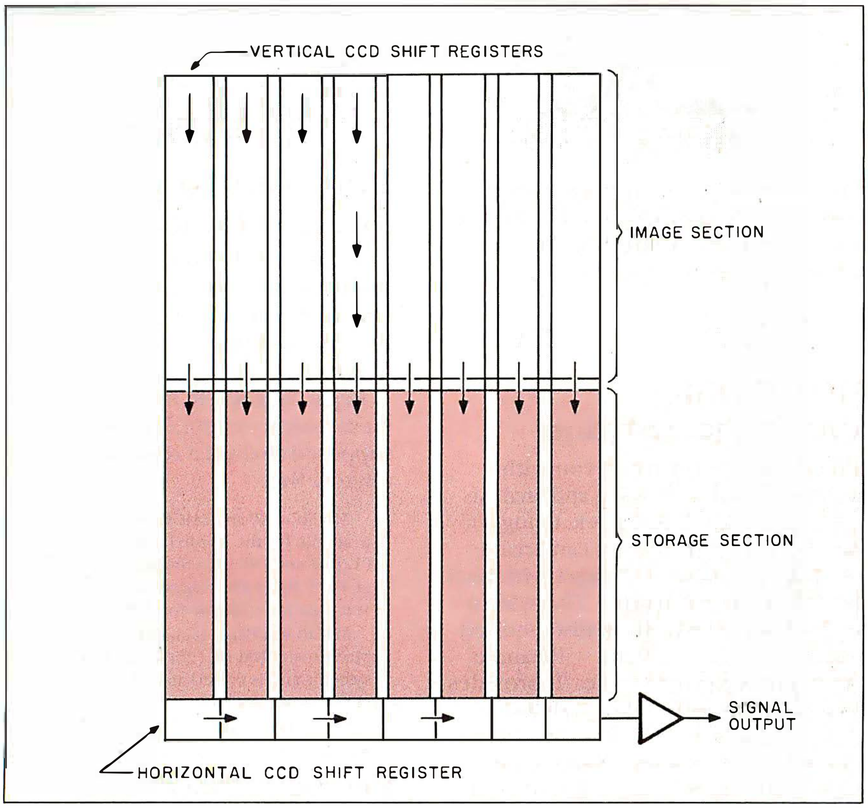


Figure 6: *A diagram of a frame transfer* CCD.

FRAME TRANSFER

In the frame transfer organization (see figure 6), the sensor consists of vertical columns of CCD shift registers divided into two zones. One zone, where charge accumulates during integration time, is photosensitive. When integration is complete, the whole array is transferred in parallel to the opaque storage area of the second zone. Since the whole image zone is photosensitive, the frame transfer organization minimizes problems with moiré effects. Another advantage of the frame transfer CCD is that it can transmit one image while acquiring another. This gives you the flexibility to vary the integration period without changing the readout time.

COLUMN-ROW TRANSFER

A third type of solid-state sensor employs *x-y*, or column-row, addressing (figure 7) to transfer charge from the photosite to the output signal amplifier. The sensor elements are addressed by selecting individual column and row electrodes. Charge collected under the column electrode is transferred to the row electrode and amplified for output.

BLOOMING

One general difficulty with solid-state sensors is that they tend to exhibit "blooming," which is the cascading of

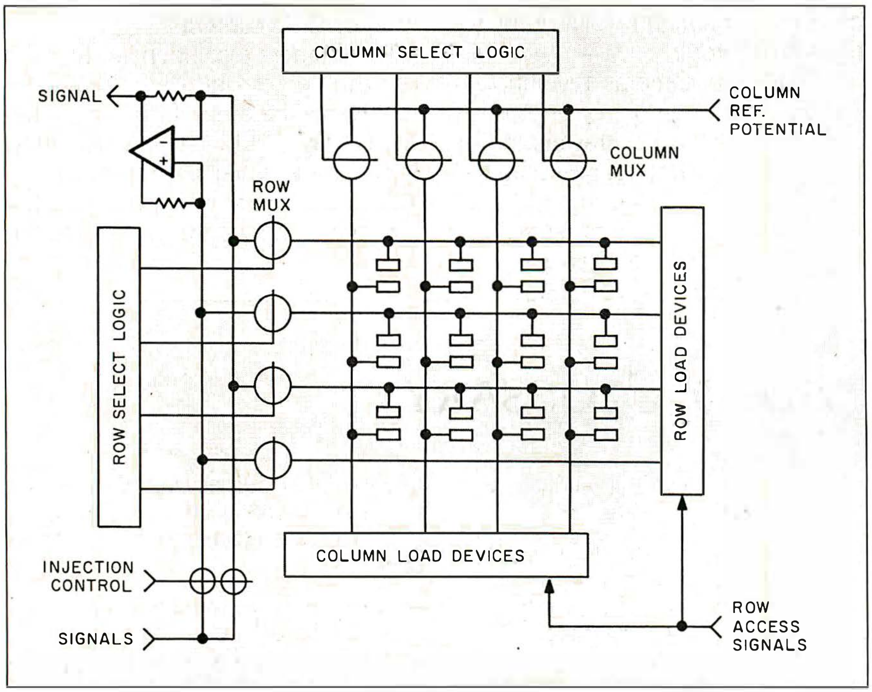


Figure 7: A *diagram of a* 4 *by* 4 CID *matrix with column-row addressing. Based on a drawing from General Electric Technical Information* GET 6803. *Used with permission of* GE.

charge saturation from a few photo elements along paths of least resistance in the sensor array. The effect is bright streaks along a single axis or both axes, extending the full height of the sensor. Scenes containing objects with specular reflections at random orientations, where light saturation is difficult to control, are especially problematic.

To effectively contain blooming, newer devices employ charge drains adjacent to the sensor cell to absorb the excess charge before it spreads to neighboring image elements.

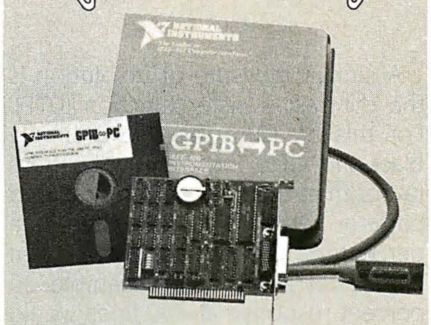
SPATIAL RESOLUTION

Whatever camera technology you use, you must concern yourself with the spatial resolution of the camera. There is considerable confusion among camera users as to what camera resolution means. It is often defined in terms of "TV lines." These units should not be confused with raster lines or the number of lines electronically scanned in the image. Lines of resolution correspond to the maximum number of alternating white and black lines per frame height or width that can be resolved by visual inspection. Often people will test resolution in both the horizontal and vertical axes by imaging a test pattern of converging black and white bars.

It is desirable to have equal resolution in both horizontal and vertical axes, but not all cameras do. In situations common to robotics, where objects may appear in the field of view at random orientations, you must assume that the camera resolution is the lower resolution of the two axes. Line resolution may also vary from region to region on the sensor surface, particularly on the peripheral areas of tube cameras.

A less subjective measure of resolution is the modulation transfer function (MTF), which relates output signal amplitude to the light image created by a bar pattern of sinusoidal variation in gray level. The function is normalized to 100 percent, where it levels off to a maximum for low spatial frequencies.

(continued)



A similar measure of resolution is the contrast transfer function (CTF). For this measure, we use a simple black-and-white "square wave" pattern rather than the sine wave modulated pattern. Resolution is specified as a percentage of response for a given number of TV lines. For example, 20 percent response at 800 lines would be considered high resolution by today's standards.

In solid-state cameras, resolution is limited by the number of photosites on the sensor, by the array geometry, and by how much opaque material separates the photosites. Charge leakage adversely affects resolution, as does transfer inefficiency in the case of CCD cameras.

Tube camera resolution is a function of the electron-beam diameter relative to the area of the photoconductive layer. Tube camera resolution is generally higher than that of solid-state cameras and easily outstrips the limitations imposed by the RS-170

(continued)

A Video Glossary

Aliasing: The kind of misrepresentation that results from pixel density being too low to represent the spatial frequencies in an image.

Blooming: A phenomenon whereby streaks fan out in the image around an area of intense illumination. Blooming occurs when excess charge in the sensor cell overflows into neighboring CCD registers. This can be suppressed by introducing overflow drains under or adjacent to the photosensitive area.

Candela: Intensity of a point source that generates one lumen per steradian (unit solid angle). Also called candle power. Abbreviated cd.

CCD: Charge-coupled device. A monolithic silicon structure in which discrete packets of charge are transported from position to position by sequential clocking of an array of gates.

CCIR: Consultative Committee, International Radio. International standard for composite monochrome video signals.

Chrominance: Indicates the hue and saturation of a color or the color information without the brightness.

CID: Charge injection device.

CPD: Charge priming device.

CTF: Contrast transfer function. Similar to MTF but uses a black-and-white test pattern.

Definition: Number of sensor cells per line/column.

Dynamic range: Ratio of the output voltage at saturation and RMS noise in darkness.

Exposure: Result of illumination over a given integration time.

Gamma (γ): A numerical value representing the exponent in a function that relates illumination to response. A gamma of 1 yields a linear response. A gamma of more than 1 results in a greater slope for bright illumination, and a gamma of less than 1 results in a greater slope for low illumination.

Integration time: Time allowed for light impingement on a given sensor cell.

Lag: Persistence of image charge over subsequent frames.

Lumen: The amount of luminous flux on a 1-square-foot area of a 1-foot radius sphere cast by a 1-cd light source at the center.

Luminance: Indicates the light intensity without the color.

Luminous flux: Luminous power per unit area.

Marking: Regional degradation of an electron tube from excessive exposure.

Moiré effect: Interference between the spatial frequency of the sensor structure and spatial frequencies in the image.

MTF: Modulation transfer function. The signal output of the sensor in response to a standard test pattern consisting of sinusoidal variations in gray-level density over a range of frequencies.

NTSC: National Television Systems Committee. A standard observed by the U.S.A., Canada, Japan, and most countries in the Western Hemisphere.

Nyquist limit: Upper limit of spatial resolution based on the spatial frequency of the placement of sensor elements.

PAL: Phase Alternation Line. A system in which the subcarrier phase is inverted from one raster line to the next. A standard observed by most European countries.

Pixel: Picture element or sensor element or photosite.

Pixel blemish: A pixel is blemished if it has a response not within an acceptable percentage of the average.

Resolution: Number of image lines per frame height with a contrast above or equal to 50 percent.

Response: Amplitude of output voltage per unit of light exposure.

Response nonuniformity: Difference in response between the most and least sensitive regions of the sensor under uniform illumination, expressed as a percentage of the average.

Saturation: Maximum amount of charge stored by a given sensor cell.

Saturation voltage: Maximum output voltage for sensor saturation.

SECAM: Système Électronique Couleur Avec Memoire. A standard observed by France and most Eastern bloc countries.

Sensitivity: Minimum illumination required to generate a usable signal.

Spectral range: Portion of the light spectrum over which the sensor has a response above 10 percent of the peak-to-peak voltage.

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Table 1: *Commercially available cameras and their features.*

Vendor	Camera	Sensor	Resolution	MTF	Minimum Illumination	Signal/ Noise	Pixel Size	Gamma
Circon 749 Ward Dr. Santa Barbara, CA 93111 (805) 967-0404	MV 9015-H	MOS array 648 (H) x 485 (V)	480 lines (H), 330 lines (V)		20 lux with f1.6 lens	42 dB		1.0 or 0.45 selectable
Cohu Inc. Electronics Division 5755 Kearny Villa Rd. POB 85623 San Diego, CA 92138-5623 (619) 277-6700	Model 4600	Interline transfer CCD 384 (H) x 490 (V)	285 lines (H), 480 lines (V)			50 dB		0.45 or 1.0 selectable
Cohu Inc. Electronics Division 5755 Kearny Villa Rd. POB 85623 San Diego, CA 92138-5623 (619) 277-6700	Model 5402	Vidicon E5405 (Chalnicon E5415 option)	Center 900 lines (H), corner 600 (H)		1 lux	54 dB	NA	0.5 to 1.0 adjustable
EG&G Reticon 345 Potrero Ave. Sunnyvale, CA 94086-9930 (408) 738-4266	MC9256	MOS photodiode array 256 x 256				60 dB		
Fairchild CCD Imaging 3440 Hillview Ave. Palo Alto, CA 94304 (415) 493-8001	CCD3000	Interline transfer CCD 380 (H) x 488 (V)	285 lines (H), 488 lines (V)	50% (CTF) at 488 lines (V)	20 lux with f1.4 lens	50 dB		1.0
Fairchild CCD Imaging CCD 3440 Hillview Ave. Palo Alto, CA 94304 (415) 493-8001	CCD 4001	Interline transfer CCD 256 (H) x 256 (V)						
General Electric 890 7th North St. Liverpool, NY 13088 (315) 456-2832	TN 2509	CID 260 (H) x 253 (V)		80% at limiting resolution		50 dB at saturation	28 x 28 μm	1.0
Hitachi Denshi America Ltd. 175 Crossways Park West Woodbury, NY 11797 (516) 921-7200	KP-120	MOS array 320 (H) x 244 (V)	240 lines (H), 190 lines (V)		5 lux with f1.4 lens	49 dB		
Imagerie, Industrie, Systeme (I2S) 239 rue du Jardin-Public 33300 Bordeaux, France (56) 29-10-03	IS 400	Frame transfer CCD 384 (H) x 576 (V)			3 lux	68 dB	23 x 23 μm	1.0

Response Uniformity	Geometric Distortion	Output Signal	Weight	Power Consumption
		RS-170	170 g (camera head)	10 W
		RS-170	511 g	5.5 W
	0.5%	RS-170, CCIR	450 g (camera head)	24 W
± 10% at saturation		Clock rate 525 kHz to 8 MHz at ± 1V or RS-170 with MB9000 data formatter	340 g	5 W
		RS-170	1 kg	
		RS-170	1 kg	
		RS-170	383 g	2.5 W
		RS-170	400 g	5 W
± 5%		RS-170, CCIR, 6-bit digital		

standard in the vertical axis.

One point that complicates evaluating resolution is that the host computer may digitize the output signal at a rate inconsistent with camera resolution.

NOTEWORTHY CAMERAS

Table 1 lists a selection of commercially available cameras. As anyone who has worked from manufacturers' specification sheets knows, however, the information provided by one manufacturer is not always readily comparable to the information provided by another manufacturer. Therefore, to help you evaluate the different cameras, I want to mention some aspects of particular cameras that we at Analog Devices have found particularly desirable for machine vision.

The GE cameras use a proprietary charge injection device (CID) sensor that contains an array of column-row addressed MOS sensor cells. The camera can be applied effectively with strobe lighting to capture transient events like moving objects. You can inhibit normal destructive readout of the camera's sensor until the event occurs, when light from the strobe generates the signal charge. Releasing the inhibit signal allows you to read out the signal. Another application of the inhibit feature is to extend the integration period of the sensor longer than the normal 50 or 60 Hz standard frame time. Extended integration allows you to accumulate more charge where scene lighting is low. With a format of 260 horizontal by 253 vertical pixels, the TN2509 camera has a symmetric aspect ratio and linear response.

For high resolution in a solid-state camera, VSP labs has the SC500 with 604 horizontal by 576 vertical photo elements. The sensor is a CCD array with high sensitivity in the blue region and a 1:1 aspect ratio.

ITM Corporation's Model 5000 Datavision has excellent response linearity and a typical spatial uniformity (response nonuniformity) of about 4 percent. The Model 5000 features

(continued)

Vendor	Camera	Sensor	Resolution	MTF	Minimum Illumination	Signal/ Noise	Pixel Size	Gamma
Image Technology Methods Corp. 103 Moody St. Waltham, MA 02154 (617) 894-1720	Model 5000 Datavision	CCD 384 (H) x 491 (V)	280 lines (H), 350 lines (V)		3 lux with f1.4 lens, without IR filter	45 dB	23 (H) x 13.4 (V) μm	1.0
Javelin Electronics 19831 Magellan Dr. Torrance, CA 90502 (213) 327-7440	JE-2062	MOS array 384 (H) x 485 (V)	500 lines (H)		30 lux with f1.4 lens	43 dB		0.45
Panasonic Industrial Co. One Panasonic Way Secaucus, NJ 07094 (201) 348-7000	WV-CD10	CPD 404 (H) x 256 (V)	280 lines (H), 190 lines (V)		10 lux with f1.4 lens, IR filter	46 dB		
Physitec Corp. 206 Main St. Norfolk, MA 02056 (617) 528-4100	43-0031	Frame transfer CCD 604 (H) x 575 (V)			0.1 lux		10 (H) x 15.6 (V) μm	
PULNiX America Inc. 453-F Ravendale Dr. Mountain View, CA 94043 (415) 964-0955	TM-34K	Interline transfer CCD 384 (H) x 491 (V)	280 lines (H), 350 lines (V)		3 lux with f1.4 lens	45 dB	23 (H) x 13.4 (V) μm	
RCA Closed Circuit Video Equipment New Holland Ave. Lancaster, PA 17604 (717) 397-7661	TC2900	CCD 403 (H) x 512 (V)		50% at 200 lines (H)	0.025 lux	52 dB		0.5 to 1.0 adjustable
Sanyo Industrial Video Division 1200 W. Artesia Blvd. Compton, CA 90220 (213) 537-5830	VDC3800	Frame transfer CCD 572 (H) x 485 (V)	420 lines (H), 400 lines (V)		2 lux with f1.4 lens	46 dB		
Sierra Scientific Corp. 2189 Leghorn St. Mountain View, CA 94043 (415) 969-9315	DAV-26	Plumbicon (other tubes available)	1000 lines (H), 700 lines (V)	20% at 1000 lines (H)	3 lux	36 dB typical	NA	
Sony Component Products Division 15 Essex Rd. Paramus, NJ 07652 (201) 368-5001	XC-38	Interline transfer CCD 384 (H) x 491 (V)			3 lux with f1.4 lens, without IR filter	46 dB	23 (H) x 28 (V) μm	
Video Logic Corp. 597 North Mathilda Ave. Sunnyvale, CA 94086 (408) 245-8622	CDR-460	Interline transfer CCD 384 (H) x 491 (V)	250 lines (H), 350 lines (V)		3 lux	46 dB	23 (H) x 13.4 (V) μm	
VSP Labs Inc. 670 Airport Blvd. Ann Arbor, MI 48104 (313) 769-5522	SC500	Frame transfer CCD 604 (H) x 576 (V)	400 lines (H), 400 lines (V)	70% at 400 lines	20 lux with f1.4 lens	30 dB	10 x 15.6 μm	1.0 or 0.6 option

Response Uniformity	Geometric Distortion	Output Signal	Weight	Power Consumption
4% typical		RS-170, 8-bit digital	1.36 kg	
		RS-170, CCIR	300 g	2 W
		RS-170	600 g	6.8 W
		CCIR		
		RS-170	122 g	
		RS-170	900 g	7.2 W
		RS-170		5 W
10% peak-to-peak	1.0%	RS-170	5.9 kg	100 W
		RS-170	115 g	2.3 W
		RS-170	545 g	
		RS-170	1 kg	

standard RS-170 output with an optional 8-bit digital output at 7 MHz.

Another notable camera for robot vision is the I2S IS400. The sensor is a 384 horizontal by 574 vertical frame transfer CCD array with symmetric photo elements. Output options include RS-170, CCIR, or 6-bit digitized data at TTL levels. The outstanding feature of the IS400 is the Monoshot, or image-gating, mode. Monoshot allows the host to trigger the start of charge integration and control the time period of charge integration. With integration periods possible from 3 to 100 milliseconds, you can use the camera to capture moving objects under good lighting conditions or to image static scenes under poor illumination.

EXPECTATIONS

We are reaching the performance limitations of RS-170 and CCIR standards as sensor resolution improves. With the price of flash converters coming down, it would make sense to design cameras for machine vision with the converter in the camera—as close to the sensor as possible—to minimize signal noise and degradation. A multidrop bus with camera select and handshake would enable the host computer to select one of several cameras on the bus and send commands. Data would be received as a serial byte stream. Useful commands might include window coordinates where only a subregion of the scene is of interest, programmable gain, subsampling rate, or variable integration time.

Feature and distance gauging requires that pixel cells be symmetrical in both horizontal and vertical axes, and most sensor manufacturers recognize this. Sensitivity, dynamic range, and uniformity are improving as weight, power consumption, and package size decrease.

In the future, we hope to have the ability to perform pixel processing at the sensor level. Operations like edge enhancement or even object detection could be performed before the data is passed to the host, thus lowering traffic on the bus. ■

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ROBOTIC TACTILE SENSING

BY KIRK E. PENNYWITT

Coming to grips with tactile sensors

TODAY'S INDUSTRIAL ROBOTS perform a variety of tasks, and robotic applications are steadily increasing. Nevertheless, robots currently in use are quite primitive; at best, they possess only a rudimentary awareness of their surroundings. As a result, they are generally limited to performing precisely defined tasks in a highly structured environment.

The controlled environment of a factory floor is considerably different from the unstructured and complex world in which most humans live and work. The robots of the future should be able to adapt to any work environment because it is often not practical to adapt the environment to them. Robots of the future should also be able to work with the same tools and equipment—conventional wrenches, hammers, pliers, screwdrivers, and so on—that human workers use. For robots to achieve these goals and attain more widespread use, they must be equipped with more sophisticated sensory capabilities that resemble those of a human.

Of the five human senses, only vision and touch are really required for a successful and adaptable robot. (Although hearing could be useful for the reception of oral commands by a robot, it is not a truly necessary capability. The use of ultrasonic ranging techniques has been investigated for proximity sensing, but interference from the loud noises common in an industrial environment remains an obstacle.)

VISION AND TOUCH

The capabilities of vision and touch are generally seen as complementary for most future robotic applications. Vision is obviously important for object identification and obstacle avoidance. It is considered a prerequisite process for locating, positioning, and identifying objects and also as a proximity sensor for the robot hand or end effector. Touch, or tactile sensing, then takes over for subsequent manipulations in which force, pressure, and compliance are important factors.

For many applications, the sense of touch is often considered more important than vision during manipulation. A robot must be able to judge when contact is made with an object and know how much force is being exerted upon that object.

A robot should also be able to determine when slip is beginning to occur and when the object is positioned properly in its intended location. In the past, greater attention has been devoted to visual sensing, but robotic touch is now beginning to attract more attention.

In this article I will provide an overview of robotic touch sensing, some of its problems, and some of the more promising approaches.

TACTILE SENSING

In robotic applications, we are concerned with tactile sensing, or *taction*, rather than simple touch. The term taction was coined by the late Professor Leon D. Harmon of Case Western Reserve University, one of the pioneers of tactile-sensing research.

Tactile sensing is defined as the continuous sensing of variable contact forces, commonly by an array of sensors. This sensing should be capable

(continued)

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of being performed within an arbitrary three-dimensional space. This distinguishes taction from touch, or binary sensing, which is simple contact or force sensing at a single point. Tactile sensing generally refers to skinlike properties where areas of force-sensitive and displacement-sensitive surfaces are capable of reporting graded signals and parallel patterns of touching.

Tactile sensing may be viewed as a two-step process: (1) transduction and (2) data processing. Transduction occurs when the features of an object being examined are converted into signals of some form, as in the case of the translation of forces into electrical impulses. Data processing then interprets these signals to obtain useful information about the features of interest.

Since it is often stated that a robotic tactile sensor should have capabilities similar to that of human touch sensing, we should briefly examine human tactile perception.

Kinesthesia versus Cutaneous Responses

Human tactile perception consists of two separate and distinct components: *cutaneous* and *kinesthetic* responses. The cutaneous response conveys touch, force, slip, and temperature information via the sensitive nerve arrays on the fingertips. This type of capability is what is usually thought of when considering robotic tactile sensing.

The kinesthetic response plays a very significant role in the sense of touch. Kinesthesia is the sensing of limb and joint position. It includes both *afferent* incoming signals developed at muscles and joints and *efferent* outgoing signals that are *motor* muscle action commands.

The combined cutaneous and kinesthetic senses are sometimes referred to as *haptic* perception. Together, cutaneous and kinesthetic stimulation allow a person to perceive objects of three dimensions and events in three-dimensional space.

Cutaneous sensations provide the perception of texture and details of shape. Kinesthesia allows the detection of larger contours and enables a person to control exploratory movements. Cutaneous stimulation and kinesthesia must work together for an organism (or robot) to be able to actively explore and perceive its tactile environment. Current research in robotic taction focuses almost exclusively on the cutaneous aspects of touch. Since a satisfactory approach to the development of a cutaneous-like sensor has yet to be achieved, it is perhaps premature to be overly concerned with the lack of attention devoted to the kinesthetic aspects of touch sensing. However, it is impor-

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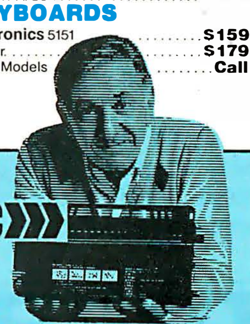
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tant to realize that both of these components should be integrated to develop a successful robotic tactile sensor.

Cutaneous sensations are conveyed by the skin. The skin's structure, sensitivity, and density of nerve-sensing sites vary considerably over the extent of the human body. Within the hand, the sensitivity may vary by an order of magnitude from the palm to the fingertip. The properties and sensory capabilities of fingertip skin most closely resemble those desired for robotic tactile sensors.

TACTILE RESOLUTION

Estimates of the spatial resolution of the fingertips vary from 0.8 to about 3 millimeters. The coarser estimates are based on two-point threshold tests, where two sharp points are pressed against the skin and the minimum separation distance required to determine that two points are being applied is measured. With this method, estimates of spatial resolution range from 2 to 3 mm.

Other methods of determining resolution include detecting gaps in a surface applied to the finger, determining the orientation of a fine grating, and identifying the forms of alphabetic characters. The last three methods yield resolution estimates closer to 0.8 mm. The higher resolutions obtained in these latter examples seems to indicate that when larger touch areas are involved, additional information is obtained that allows finer perceptions.

Tactile acuity is more than just a function of the sensory unit density. It also depends on the relative portion of the brain devoted to tactile representations and on the structure of the skin itself. It has been demonstrated that the brain region devoted to tactile processing can change and in turn alter tactile acuity.

Experiments on monkeys show that upon loss of a finger, the brain region devoted to the remaining fingers grows to include the region previously devoted to the amputated finger. The tactile acuity for the remaining fingers improves substantially. Moreover, the role of any individual nerve cell is believed unimportant; rather, networks of thousands of cells provide tactile response.

In addition, the structure of fingertip skin, particularly the papillary ridges (the raised ridges on the fingertips that produce fingerprints), may contribute to tactile perception. During fine movements of the fingers, the ridges create vibratory effects that propagate through the various skin layers, adding to tactile pattern recognition. These phenomena illustrate that the data-processing aspects of tactile sensing should be considered at least as important as the transduction concerns.

TACTILE SENSING VERSUS VISION

Tactile sensing is analogous to visual sensing in many respects. Both sample continuous signals over a two- or three-dimensional space and share a common model of the outside world. Both must employ pattern-recognition techniques to interpret the spatially sampled pattern representations of their environment. These similarities may allow tactile sensing to derive benefits from the considerably greater effort that has already been devoted to visual sensing.

However, taction has many advantages over vision for physical manipulation tasks, which, of course, include almost all commercial and industrial applications. With taction, the physical properties being directly measured are those we are most interested in—object position, shape, texture, surface detail, and so on. Vision can infer these properties only indirectly by deducing them from optical properties (shading, projection, reflectivity, etc.).

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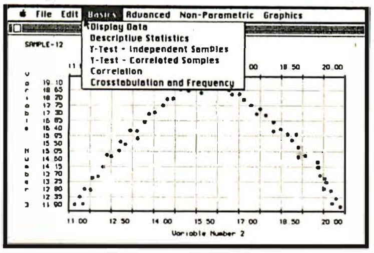
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The collection of tactile data is more readily controlled because the sensor is generally in actual physical contact with the object being examined. This eliminates potential problems involving uneven illumination, confusing background image information, or camera point-of-view constraints. There is also potentially less data to analyze in a tactile versus a visual representation. A tactile sensor is obviously ideal for pressure, slip, and incipient-slip detection as well.

On the other hand, tactile sensing involves several unique problems. With vision, the three-dimensional reconstruction of the object (based on the two-dimensional camera image) may be done by a powerful central processor that is remote from the sensor.

For taction to be useful, you must be able to actively manipulate and explore the object being examined. This requires not only the transduction to be performed at the object site but a large amount of real-time data processing to be performed there as well.

Because a visual sensor is remote from the subject at all times, it faces only moderate constraints on physical size and placement. However, a tactile sensor is normally an integral component of a robot end effector and thus must conform to strict size and shape constraints. In addition, the sensor itself must be capable of resisting abrasion, heat, and chemicals present in the industrial environment.

REQUIREMENTS OF A TACTILE SENSOR

The exact requirements of a particular tactile sensor depend on its specific application. However, there is a consensus among actual and potential robot users on the capabilities a general-purpose tactile sensor should possess.

The most commonly stated requirement is that the sensor be skinlike. It should exhibit high sensitivity, fast response time, continuously variable signal output, and low power consumption. It should also be cheap and durable.

The ideal end effector should be handlike. Touch, force, pattern, slip, and movement detection should all occur in one device. Forces transferred to the support structure should be used for analyzing larger signals (kinesthetic versus cutaneous sensing). Finally, the hand should be intrinsically "smart." That is, a significant amount of data preprocessing should be done at or near the sensor. Low-level data processing should take place at the sensor level, including detection of information regarding edges, holes, etc.

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Prosthetic and orthotic needs for the handicapped are an important use for manipulators and tactile sensors.

users indicate that the spatial resolution required for a useful tactile sensor is approximately 1 mm. For a manipulator of the same approximate size as a human fingertip, this implies a sensor array of from 5 by 10 to 10 by 20 elements.

The sensor should have a sensitivity on the order of 1 gram and should have an upper-limit capability of approximately 1000 grams. (A logarithmic response would be satisfactory for most users.) Nonlinearity in the response of the sensor is generally tolerable because it can be compensated for in the data-processing software. Hysteresis in the sensing device, however, is absolutely intolerable. (Hysteresis is a characteristic of many materials whereby a physical parameter, such as electrical response, varies markedly depending on whether the phenomenon on which it depends is increasing or decreasing.)

A sensor's response should be stable and repeatable, and its response time should be short. The sensor transduction bandwidth requirements vary from 100 to 1000 hertz. That is, the data from the sensor should be updated at least every 10 milliseconds and preferably every 1 millisecond. (It is interesting to note that human touch is fairly hysteretic and that the transduction bandwidth ranges from 20 Hz for separate touches to several hundred Hz for vibration sensing.) The sensor must also be durable and capable of withstanding the rigors of an industrial environment.

Applications for tactile sensors include manipulation, teleoperation, and prosthetic and orthotic needs. Industrial uses include assembly, casting and molding, forging, grinding and polishing, heat treating, machining, painting, pouring, sorting, stacking, transporting, and welding. Many agencies, particularly the military, have uses requiring robots with tactile sensing capabilities. These include undersea exploration and salvage, prospecting, space-station operations, mining, and hazardous factory, power plant, and rescue operations.

Tactile sensing is ideally suited for use in obscured environments, such as murky water and smoky rooms. Teleoperated manipulators require accurate force feedback, stable grasping, position sensing, detection of slip, and light touch. This area of sensing has received surprisingly little significant attention.

Prosthetic and orthotic needs for the handicapped are another important use for manipulators and tactile sensors. These include artificial limbs for the amputee and sensing and assist devices for the paralyzed. The requirements for prosthetic and orthotic aids are primarily the same as for teleoperation: stable grasping, light touch, slip detection, and so on.

Half of the estimated 7,500,000 disabled persons in the U.S. could probably be helped to some degree with presently available robotics technology.

Despite the considerable list of needs for effective touch sensing, the present state of the art remains extremely primitive. Automated tactile sensing is at a very early stage of investigation, comprehension, and capability. Until very recently, touch feedback systems for robots and manipulators were quite simple and relatively crude.

Today's industrial systems still employ extremely simple devices; almost all of the more sophisticated, complex, and potentially useful tactile sensors are still in laboratory development, primarily in the academic or government environment (see table 1).

However, the transition from simple contact sensing to full robotic taction is under way. A great deal of research is currently being devoted to tactile sensing, and many promising approaches are being investigated.

APPROACHES

The design of a tactile sensor is influenced by its intended use. The major applications for tactile sensors can be divided into three general categories:

1. Simple pressure determination and slip sensing. These capabilities are necessary for the most common industrial applications of handling a workpiece without damage.
2. Determination of object orientation and position. This is required for more complex and unstructured applications, such as picking an object from a bin, orienting it into a new position, and assembling it with other objects.
3. Object identification or recognition. This feature is necessary for advanced applications in which a robot may be working in a totally unknown environment (such as undersea exploration) and may be required to classify or identify an object based solely on tactile sensations.

Each of these applications involves a different design approach and different computational requirements. The first application is technically the simplest to implement, and industry has found several workable approaches to it. The latter two applications are the most challenging, and it is on these applications that most of the current laboratory research is focused.

The mainstream of current tactile sensor research can be divided into three broad categories, distinguished by their fundamental principles of operation: sensors using electro-optical, piezoresistive, or piezoelectric properties.

ELECTRO-OPTIC TACTILE SENSORS

Electro-optic sensors rely on the modulation of a light source by the

(continued)

Table 1: *A comparison of robotic tactile sensors and their characteristics.*

Sensor	Principle	Spatial Resolution	Bandwidth	Force Sensitivity	Load Range	Status	Advantages	Disadvantages
Ideal Sensor (Harmon Compilation)	—	1 mm	100–1000 Hz	1 gm	1–1000 gm	Hasn't been invented yet	General-purpose, no hysteresis, high resolution	None
Lord Tactile Sensor	Optic	1.8–7.6 mm	300 Hz	3 gm	0–681 gm	Commercial	Durable, little electromagnetic interference	Individual LED/ detector for each site limits ultimate resolution
MIT Sensor–Schneiter/ Sheridan	Optic	0.6 mm	30 Hz	N.A.	18:1 dynamic range	Experimental	Very high spatial resolution possible, little electromagnetic interference	Possibly high computational requirement, limited durability at present
Tactile Robotic Systems	Optic	2.5 mm	12 Hz	0.04 gm	256:1 dynamic range	Commercial	Low hysteresis, relatively inexpensive devices available for experimentation	Still relatively experimental
MIT Sensor–Purbrick	Conductive silicone rubber	2 mm	40 Hz	5 gm	5–100 gm	Experimental	Simple, inexpensive design	High hysteresis, nonlinearity
MIT Sensor–Hillis	Aniso-tropically conductive silicone rubber	0.6 mm	N.A.	5 gm	5–50 gm	Experimental	High resolution, inexpensive design	Hysteresis problems
Barry Wright Corporation Sensoflex Tactile Sensor	Conductive elastomer	1.3 mm	30 Hz	230 gm	200–50,000 gm	Commercial	Relatively low hysteresis, durable, wide load range, high repeatability	Relatively low sensitivity
Transensory Devices Inc.	Silicon strain gauge	2 mm	N.A.	10 gm	10–1000 gm	Commercial	Mature technology, low hysteresis, high repeatability	Fragile, brittle
University of Florida Induced Vibration Tactile Sensor	Piezoelectric	0.3 mm* (not yet real-time)	1 Hz	Not tested	Not tested	Experimental	Inexpensive, good for slip detection or exploration	No static response, highly experimental
University of Pisa Sensor	Piezoelectric	3 mm	100 Hz	20 gm	20–80,000 gm	Experimental	Multipurpose temperature, vibration, and pressure sensing	Static response requires increased complexity of design

* Single-element sensor, high-resolution capability based on vibrational design concept.
N.A.: Information not available.

mechanical deformation of a flexible material. An elastic membrane often forms the touch surface and is usually chosen to be tough and durable. This type of sensor is generally a completely sealed unit and is thus impervious to most industrial contaminants.

Electro-optic tactile sensors may also be highly sensitive, providing a direct readout of the degree of mechanical deformation of their touch surface and are usually less susceptible to electromagnetic interference than other types of tactile sensors. Two tactile sensors based on electro-optics are commercially available, and they represent the two most common optical approaches.

The Lord Corporation of Erie, Pennsylvania, presently markets a line of tactile sensors designated as the LTS-100, LTS-200, and LTS-300. All are based on the same principle and differ primarily in sensing area and resolution. The Lord Tactile Sensor is made up of three major components: a touch surface, a transduction array, and an electronic interface and control.

The touch surface is an elastomeric pad that contacts an object to be examined. The transduction medium consists of an array of LEDs (light-emitting diodes) and phototransistor pairs.

The light from the LED is projected across a small gap and is received and converted into an electrical current by the phototransistor. When the touch surface comes into contact with an object, a pinlike projection on the underside of the touch surface protrudes into the transduction area. This projection is forced downward into the gap between the light emitter and detector and progressively blocks the light from the LED emitter (see figure 1).

The current generated by the light detector is inversely proportional to the degree of deflection of the transduction medium. The amount of force applied at a site may be determined by the properties of the elastomeric touch surface.

The Lord LTS-100 sensor consists of an 8 by 8 array of LED/phototransistor pairs providing a total of 64 sensitive sites for pattern information. Each site is sensitive only to normal loads, and the electrical signal generated at each site is digitized to an 8-bit value to provide gray-scale information.

Photo 1 shows the LTS-100 and a sample output image. The site-to-site spacing of this sensor is 7.62 mm, and the deflection range at each site is from 0 to 1.52 mm, corresponding to 0 to 681 grams. The 7.62-mm resolution of this sensor is relatively coarse, although its sensitivity of 3.18 grams per deflection increment is fairly good.

Deflection information for the entire array is scanned and output approximately every 3 milliseconds. The LTS-200A sensor provides higher resolution by using an array of 10 by 16 sensitive sites on 1.80-mm centers. However, these sites are only digitized to 4-bit values, which reduces their sensitivity.

The Lord sensor is a durable and rugged unit. However, since the design requires that each sensitive site be equipped with its own light emitter/receiver pair, which must be individually scanned, the ultimate resolution of the sensor is limited by the physical size of the sites and the complexity of the electronics required to interpret the signals received.

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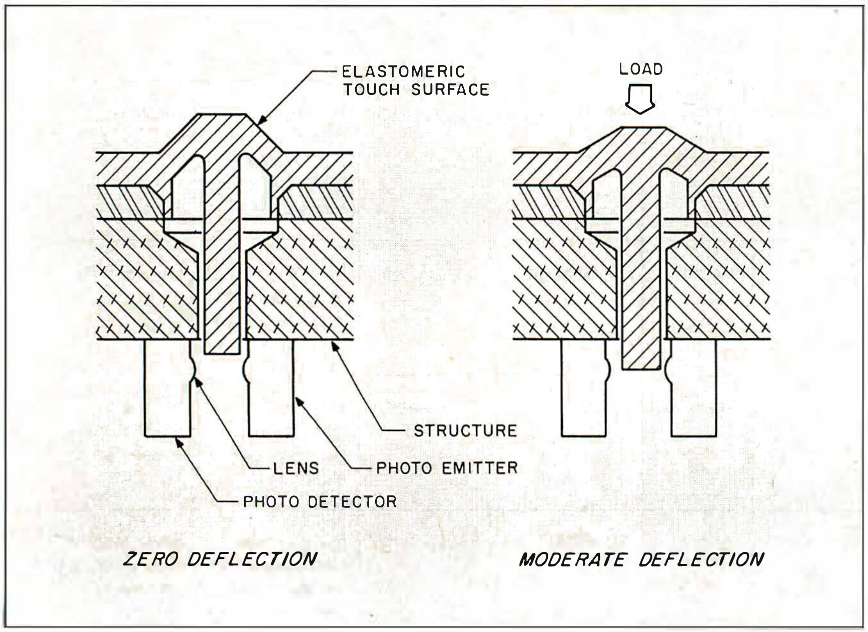


Figure 1: *Sensitive site detail of an electro-optic tactile sensor. Used with permission of Lord Corporation, Erie, Pennsylvania.*

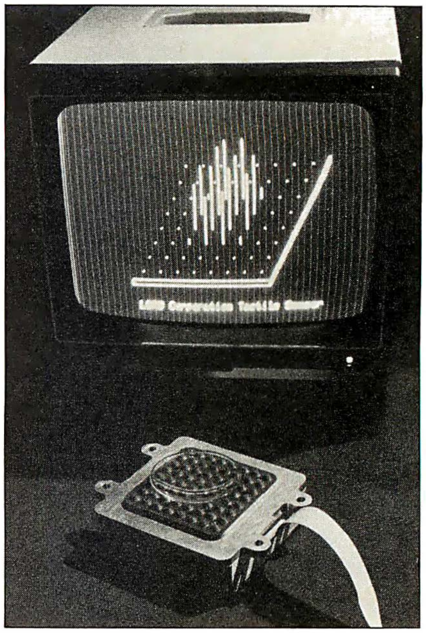


Photo 1: LTS-100 *sensor with display of tactile impression. Used with permission of Lord Corporation, Erie, Pennsylvania.*

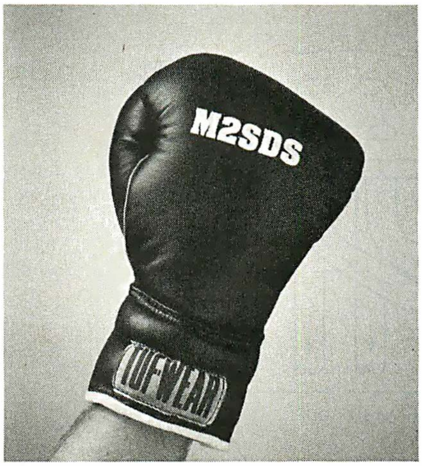
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A tactile sensor based on the use of fiber optics is illustrated by research performed at MIT by John L. Schneiter and Thomas B. Sheridan. In this approach, light is transmitted through a bundle of fiber optics to an elastic reflective surface. The light reflected back from this surface is transmitted through another bundle of fiber optics to a video camera. The camera's output is digitized and made available to a computer for processing.

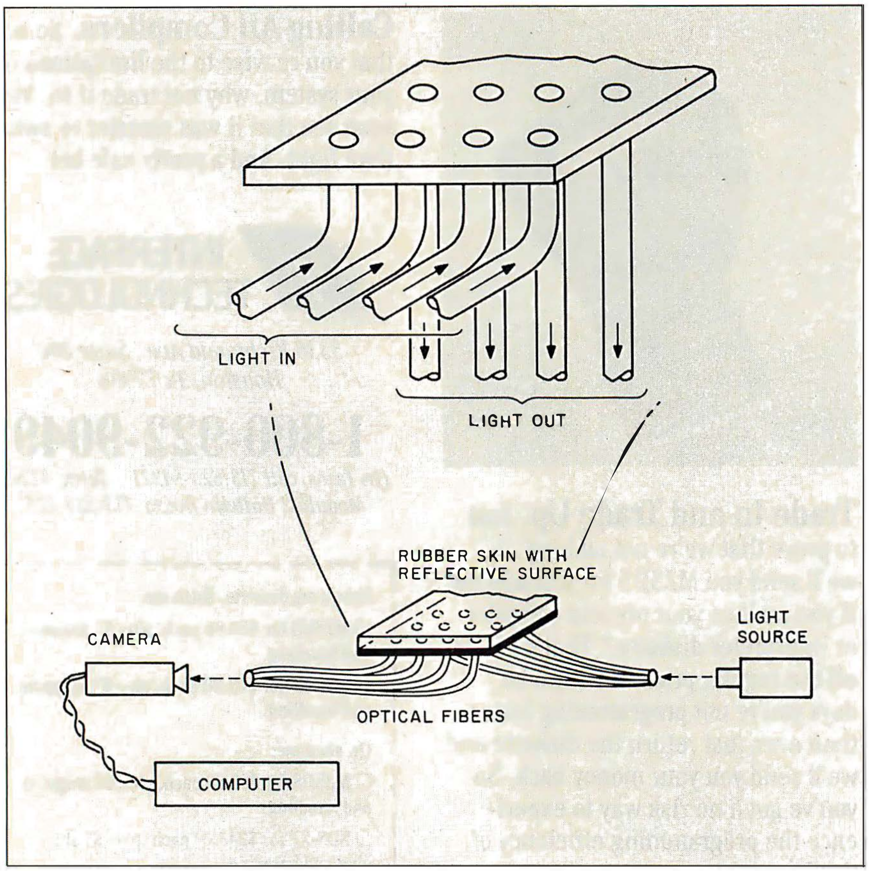


Figure 2: A *tactile sensor based on the use of fiber optics, designed by* John L. Schneiter *and* Thomas B. Sheridan. *Reprinted from* Robotics and Computer-Integrated Manufacturing. *Courtesy of Pergamon Press.*

When pressure is applied to the deformable reflector, the intensity of the light transmitted through the individual fibers changes. This information can be converted into a visual image by the computer. (The Jet Propulsion Laboratory in Pasadena, California, has developed a tactile sensor based on the same principle; however, the JPL sensor uses individual photodetectors for each of 16 fiber-optic sensors in a 4 by 4 array.)

The touch surface of the MIT sensor consists of a layer of white silicone rubber that acts as a deformable reflector. This layer is bonded to a layer of clear elastomer, to which the fiber-optic bundles are attached. Various methods of transmitting and receiving the light have been experimented with.

In one case, individual fibers were paired into emitting and receiving layers. This design, illustrated in figure 2, was somewhat difficult to fabricate because of the requirement that half the fibers be directed to the light source and the other half to the video camera.

A different design, shown in figure 3, uses each fiber for both emitting and receiving. In this implementation,

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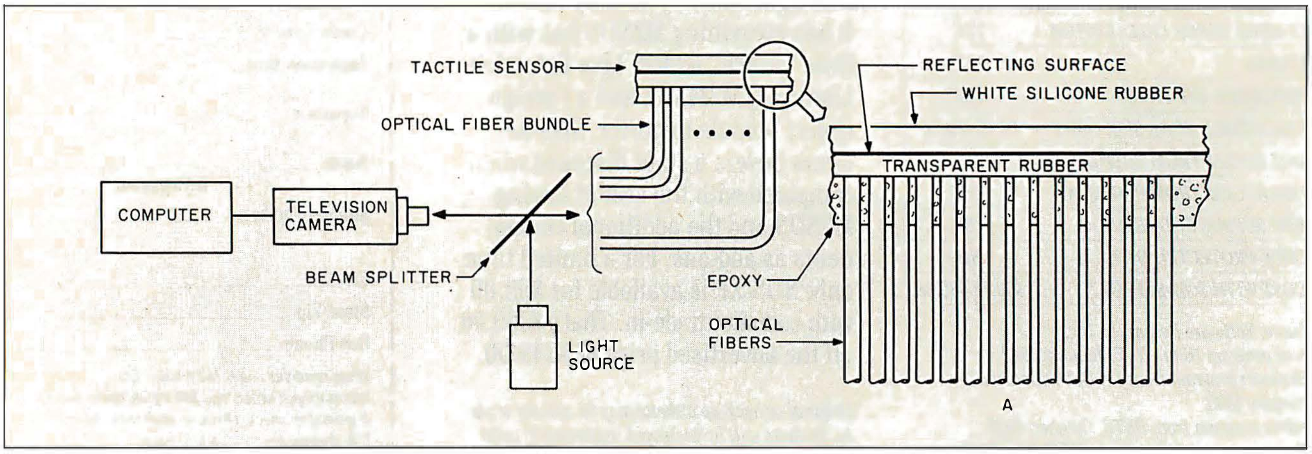


Figure 3: A *fiber-optic-based tactile sensor that uses each fiber as both emitter and receiver. Reprinted from* Robotics and Computer-Integrated Manufacturing. *Courtesy of Pergamon Press.*

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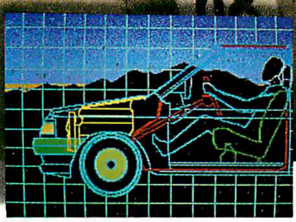
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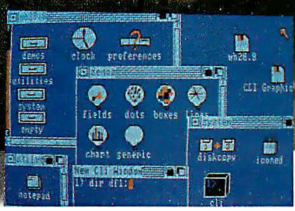
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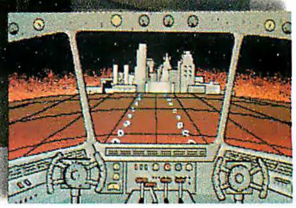
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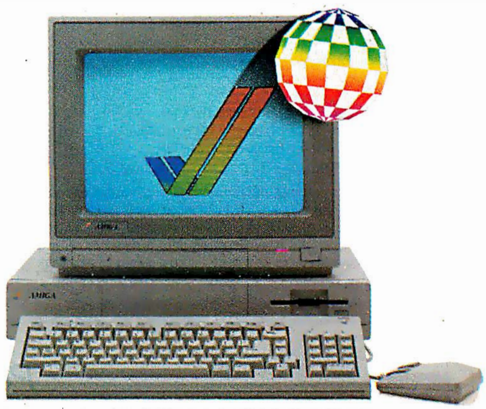
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light is directed from the light source to a beam splitter. At the beam splitter, 75 percent of the light is transmitted straight through and is lost. The other 25 percent is directed into the fiber-optic bundle and transmitted to the reflector. This light is then reflected from the reflector back into the bundle, where it again passes through the beam splitter (with 75 percent transmission) to the video camera. In this way, each fiber acts a both an emitter and a receiver, and fabrication is greatly simplified.

Because this type of sensor uses tightly packed bundles of optical fibers, extremely high spatial resolution is possible. The ultimate resolution of this type of device is limited only by the diameter of the individual optical fibers.

Schneiter and Sheridan have reported usable spatial densities of over 2100 sensitive sites per square inch, which is roughly equal to a resolution of better than 0.6 mm. The device is also completely immune to electromagnetic interference and can be used in environments that would harm computers by simply routing the fibers from the sensor to a remote location.

The prototype device is currently limited by a reaction time of 33.33 milliseconds (based on the video camera refresh rate), a somewhat restricted dynamic range of 18 to 1, and a touch surface that wears out fairly rapidly (after a few hundred cycles). It is also important to note that very high spatial resolutions, like those attained in this design, often require increased computational requirements as well.

A commercial tactile sensor combining features of both the Lord and the MIT optical sensors is available from Tactile Robotic Systems of Sunnyvale, California. The company's highest-resolution sensor consists of a 16 by 16 array of sensitive sites spaced approximately 1.3 mm apart. Each sensing site is composed of a very small cantilever spring that protrudes through a metal plate. An optical fiber passes beneath each sensing site.

The fiber has a small gap cut in it so that the two cut ends look at each other across a small air space. Light is passed through the fibers from an array of LEDs along one side of the sensor and is received by phototransistors along the opposite side. When pressure is applied to a sensing site, the cantilever spring pushes one end of the optical fiber out of alignment with the other fiber, thus diminishing the amount of light received by the photodetector at the opposite end of the fiber.

This arrangement is similar to the Lord approach, but it can provide a potentially higher spatial resolution because the light emitters and detectors are located along the sides, rather than within the interior, of the sensor array. Also, whereas the Lord sensor relies on the properties of its elastomer surface to provide the force-versus-displacement calibration, the Tactile Robotic Systems device uses the metal cantilever spring to provide a more stable and predictable spring constant.

The sensor can be calibrated to determine loads ranging from 10 to 1000 grams per sensing site. Each sensing site can resolve approximately 256 discrete steps, so the sensitivity of an individual site can be as high as 10/256 grams, or approximately 0.04 grams. The data response time of the sensor is restricted by the hardware and software of the personal computer it is interfaced to and is currently limited to a scan rate of 3 kHz for each site, or approximately 12 Hz over the entire array.

PIEZORESISTIVE TACTILE SENSORS

The category of piezoresistive tactile sensors is quite broad and includes

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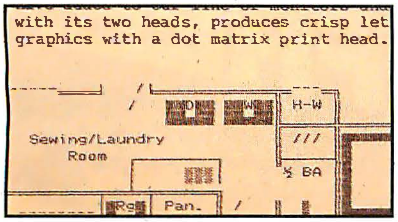
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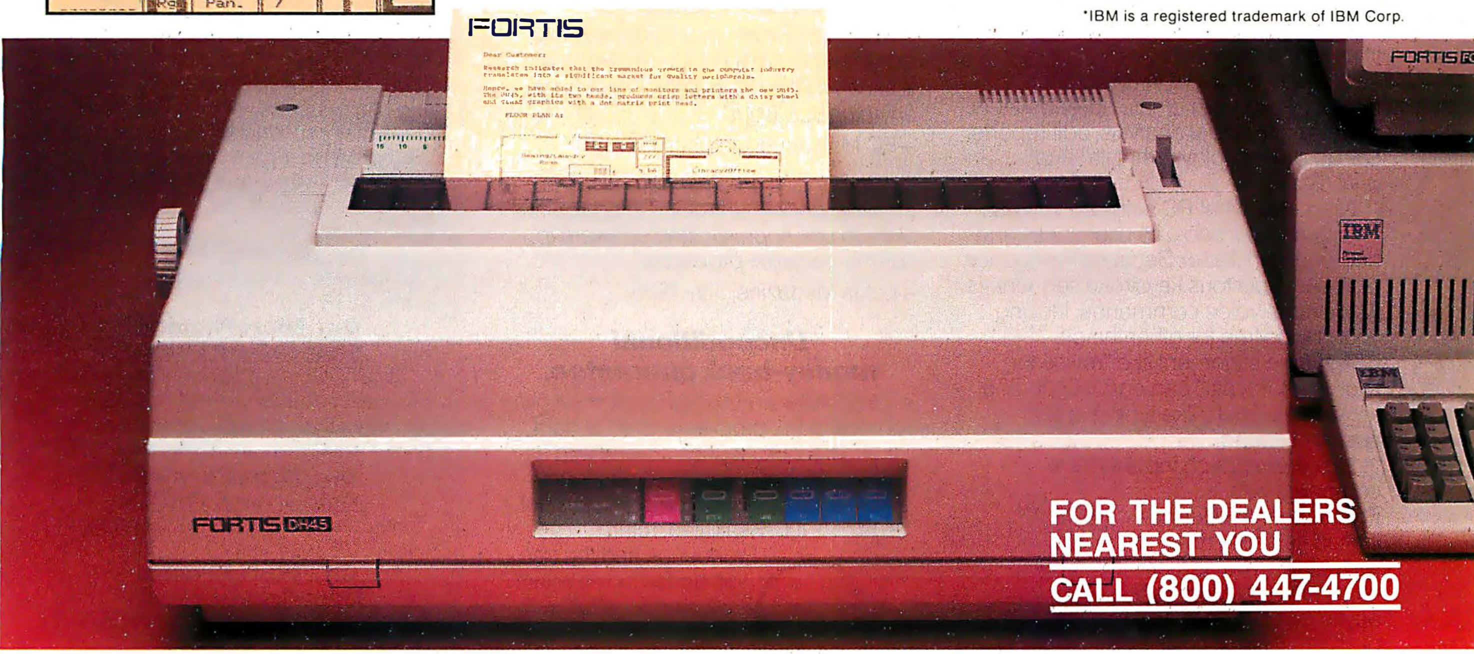
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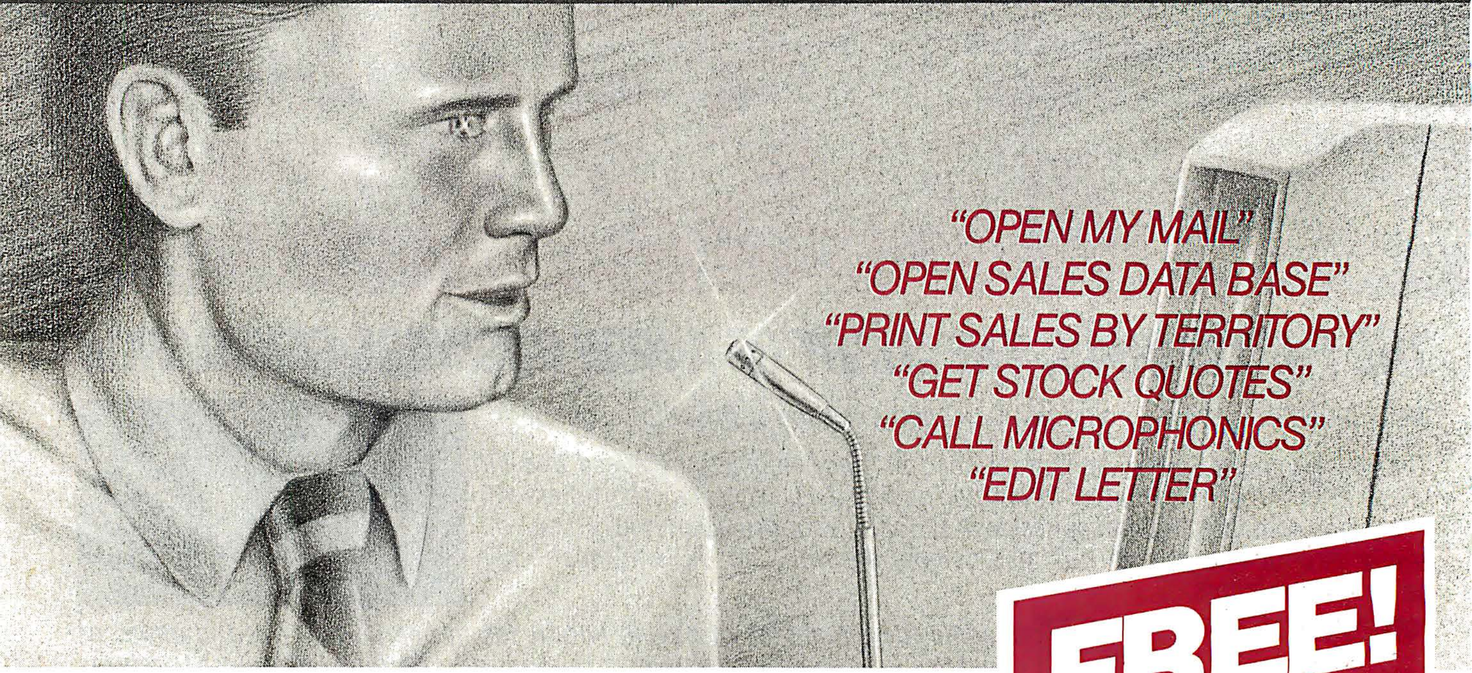
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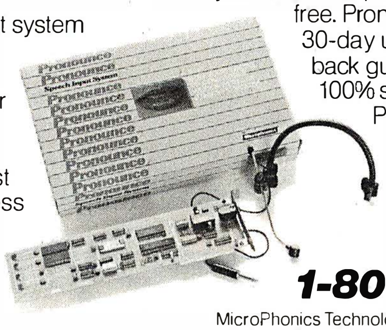
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a multitude of different device types and approaches. These range from simple strain gauges and solid-state silicon devices to conductive elastomers and foams. They are all included in this single category because all rely on materials whose electrical conductivity varies as pressure is applied.

The use of conductive elastomers as the basis for a tactile sensor has been studied for some time. A conductive elastomer is simply an elastic, rubber-like material that has electrically conductive properties. Many different conductive elastomer or conductive foam materials have been experimented with, but most sensor designs use an approach similar to that used by John Purbrick of the MIT Artificial Intelligence Laboratory.

Purbrick noted that if a flat, hard conductor is pressed against another that is rounded and compressible, the area of the electrical contact will vary according to how hard the first conductor is pushed. The greater the pressure, the larger the contact area formed and the lower the electrical resistance.

Strings of conductive silicone rubber with a semicircular cross-section were formed into two identical sets of 16 parallel lines. These were aligned perpendicular to each other and placed into contact to form a 16 by 16 array. This created 256 nodes where the convex surfaces of both sets of cords touched. An automatic scanning system passed a current into the array along a horizontal string and out across a vertical string, one combination at a time.

It was possible to measure the resistance of each of the 256 contact points in the grid approximately 40 times per second. Purbrick's device was able to distinguish at least 10 different amounts of pressure in a range from 5 to 100 grams.

William D. Hillis, also of the MIT Artificial Intelligence Laboratory, extended this approach by using sheets of a material known as anisotropically conductive silicone rubber (ACS). ACS has the useful property of being conductive along only one axis in the plane of the sheet.

A flexible printed-circuit board was etched into fine parallel lines so that it, too, was conductive in only one direction. The etched-circuit board and the ACS were placed into contact, with the lines on the printed-circuit board oriented perpendicular to the ACS axis of conduction. The contact points at each intersection of the perpendicular conductors form the pressure sensors. A springy nylon mesh (made from pantyhose material) was used to separate the contacts after pressure was released.

The array was scanned electronically to determine the applied pressure at each contact point. Hillis's device was a 16 by 16 array over a 1-square-centimeter area. It was able to reliably measure pressures ranging from 5 to 50 grams per square millimeter.

Barry Wright Corporation of Watertown, Massachusetts, markets a commercial tactile sensor based on the research of Purbrick and Hillis. However, the Barry Wright sensor uses a proprietary elastomer material, rather than silicone compounds.

The Sensoflex Tactile Sensor is currently available in two models, one made up of a 16 by 16 site array on 0.1-inch centers and the other an 8 by 16 array on 0.05-inch centers. The sensor is scanned on a row/column basis, and the output is digitized to an 8-bit value. The sensor can be scanned at rates up to 30 times per second and is designed for recommended loads ranging from 0 to 75 pounds per square inch. Barry Wright Corpora-

(continued)

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Our Objective Was Simple

We wanted to find that printer which had all the features you could want and yet be sold directly to you at the lowest price. We didn't want a "close-out special" of an obsolete product that some manufacturer was dumping, so we limited our search to only those new printers that had the latest proven technology. We wanted to give our customers the **best** printer on the market today at a bargain price.

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The search is over. We have reduced the field to a single printer that meets all our goals (and more). The printer is the SP-1000 from Seikosha, a division of Seiko (one of the foremost manufacturers in the world). We ran this printer through our battery of tests and it came out shining. This printer *can* do it all. Standard draft printing at a respectable 100 characters per second, and with a very readable 12 (horizontal) by 9 (vertical) character matrix. This is a full bi-directional, logic seeking, true descender printer.

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tion, manufacturer of the Sensoflex Tactile Sensor, claims that its product exhibits the characteristics of low hysteresis, fast response time, and high repeatability.

Strain Gauges as Tactile Sensors

Although careful material selection can minimize hysteresis and long-term creep, these effects will always be present to some degree in an elastomer material. Some researchers prefer to avoid these potential pitfalls by basing their sensor design on the more mature and proven technology of strain gauges.

In its simplest form, a strain gauge is a circuit that is capable of measuring very minute changes in the resistance of one or more of its components. When a force is applied to the gauge or to an object to which the gauge is attached, some parts of the gauge are subjected to tension or compression. This results in a small change in the physical dimensions of the gauge and can be quantified by the resultant change in the electrical resistance of the strain-gauge circuit. Strain gauges are available in a variety of shapes and sizes and offer the dual advantages of low hysteresis and low fatigue.

Transensory Devices Inc. of Fremont, California, is developing a tactile sensor based on solid-state silicon strain gauges. These miniature strain gauges allow for the relatively dense arrays of sensing sites generally considered necessary for an effective tactile sensor.

Each individual sensing site of the Transensory Devices sensor consists of a small box-shaped silicon element (called the mesa) that protrudes out of a silicon diaphragm. The mesa is capped with a protective square of hard plastic, and the whole assembly is bonded to a glass substrate housing the electrical connections. A rugged elastomer material covers the entire assembly for protection (see figure 4).

The mesa, diaphragm, and interface circuitry are all machined from a single piece of silicon wafer. In use, a 5-volt power supply provides a reference signal for the sensor, as well as power for the on-board logic circuitry. The sensor's output is an analog voltage that changes proportionally with the force applied to the sensitive area.

Two sensors have been developed and tested by Transensory Devices. One is a single-element sensor; the other is a 3 by 3 array of sensor elements spaced on approximately 2-mm centers. The present devices provide good linearity in force sens-

(continued)

ing and are designed to measure from 0 to 2 pounds of force. This design approach of miniature solid-state transducers offers great promise for future high-resolution sensors. However, the current silicon and glass sensor is both fragile and stiff and will require further refinements before it is suitable for widespread application in an industrial environment.

Piezoelectric Tactile Sensors

Piezoresistive sensors measure a change in electrical resistivity as a result of an applied force. Piezoelectric sensors are based on materials that *generate* an electrical response to an applied force. Piezoelectricity is a common phenomenon of crystalline materials such as quartz, and piezoelectric ceramics are in widespread use. However, the brittle nature of most common piezoelectric materials tends to make them unsuitable for tactile sensor applications.

A class of materials known as piezoelectric polymers offers considerable promise for tactile sensing. Piezoelectric polymers are, as the name implies, polymers that exhibit piezoelectric properties. They are rugged, durable, inexpensive, and available in thin flexible sheets that allow them to conform to complex contours.

Piezoelectric polymers may be formed into patterns of high-resolution arrays by either metalizing the polymer film through a suitable mask or by selectively etching a metalization previously deposited on the film. They are flexible, rugged, high-resolution, and inexpensive. These are some of the key characteristics of the ideal tactile sensor discussed earlier.

In addition to their piezoelectric properties, the polymers also exhibit pyroelectric characteristics. That is, they show a change in electrical response based on temperature as well as pressure stimuli. This can be a problem or an asset, depending on how it is dealt with. One piezoelectric polymer that is widely used in tactile sensor research is polyvinylidene fluoride, or PVDF. This material exhibits the desirable property of a relatively large and linear electrical response to an applied external force.

One problem with the use of PVDF or other piezoelectric materials in general is that the electrical response is inherently dynamic. That is, the material generates an electrical response only while it is being deformed. If a continuous, nonvarying load is applied to a PVDF sensor, the electrical signal generated by the load will soon decay to zero.

The Dynamic-Motion Principle

Researchers at the University of Florida dealt with that potential problem by developing a sensor based entirely on dynamic motion. The concept of a sensor based on the vibrations induced by sliding motion across a sample object was developed by Gale E. Nevill Jr. and Robert W. Patterson of the University of Florida.

This concept is based on the theory that the papillary ridges of the fingertips provide information that is useful in the identification of objects by touch. To investigate the theory, a tactile sensor was designed that would move across an object under examination.

The sensor is composed of two separate PVDF transducers. One transducer is oriented so that its direction of greatest electrical sensitivity is parallel to the direction of movement; the other is oriented transverse to that direction. The two transducers, oriented perpendicular to each other, are bonded together with nonconductive epoxy. The transducer assembly is then bonded to a silicone rubber pad.

The surface of the rubber pad is made up of a regular series of triangular ridges, meant to simulate the ridges on the human fingertip. Separate electrical leads from the parallel and transverse transducers are fed to a signal analyzer. The construction of the sensor allows for the separate analysis of the transverse and parallel vibrations induced by moving an object across the sensor.

In experimental use, objects are moved across the sensor at a constant speed via a rotating platform. When the sensor pad contacts an object, a measurement is made of the signal induced by both the transverse and parallel vibrations. This results in a signal spectrum of voltage versus frequency. Discrete values of the signal within certain bandwidths are used as parameters for a discriminate analysis pattern-recognition scheme.

During laboratory tests, sample objects are first moved across the sensor to establish a test template of parameters. Afterward, the sensor is able to recognize objects to which it has been previously exposed with almost 100 percent accuracy. It is capable of reading the Braille alphabet and can distinguish between different grades of sandpaper. It can tell

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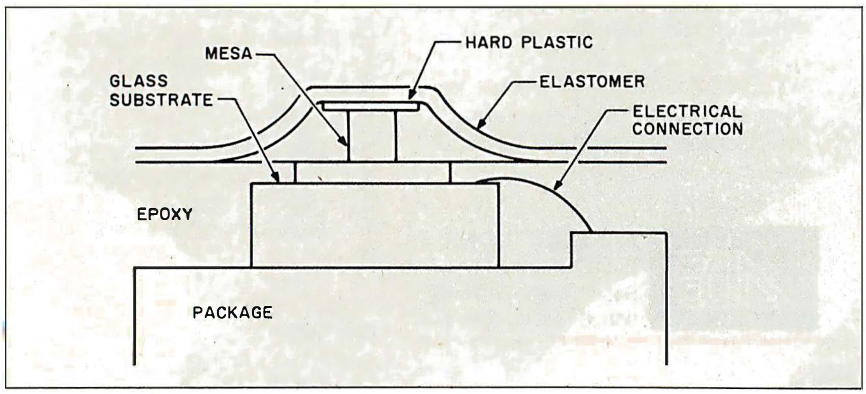


Figure 4: *The major components of a single-element tactile sensor that measures force normal to its surface. By permission of Transensory Devices Inc., Fremont, California.*

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the difference between cylinders and spheres of varying sizes and can resolve differences between ball bearings spaced 0.25 inch versus 0.26 inch apart. It can also determine the features of an object under examination even if the speed with which it is scanned across the object is changed.

More recent experiments have identified materials for the surface pad that are more resistant to temperature and abrasion than the original silicone rubber pad. Further investigations are being performed to develop sensor arrays that offer increased spatial resolution. This type of sensor shows promise in applications that are primarily exploratory or object-identification-oriented. It also appears appropriate for use in slip detection.

However, since its output depends on dynamically induced vibrations, this type of sensor is unsuitable for conventional gripping applications unless wedded with another sensor design. Also, since the computer must know the sensor's relative speed of motion, there must be communication with another device capable of determining that speed. This is not necessarily a problem, since such information could be obtained from the movement of a robot arm attached to the sensor, but it is a consideration nevertheless.

P. Dario, D. De Rossi, P. C. Pinotti, R. Bardelli, and others at the University of Pisa in Italy have been involved for many years in developing an artificial, skinlike, tactile sensor capable of alleviating some of these problems.

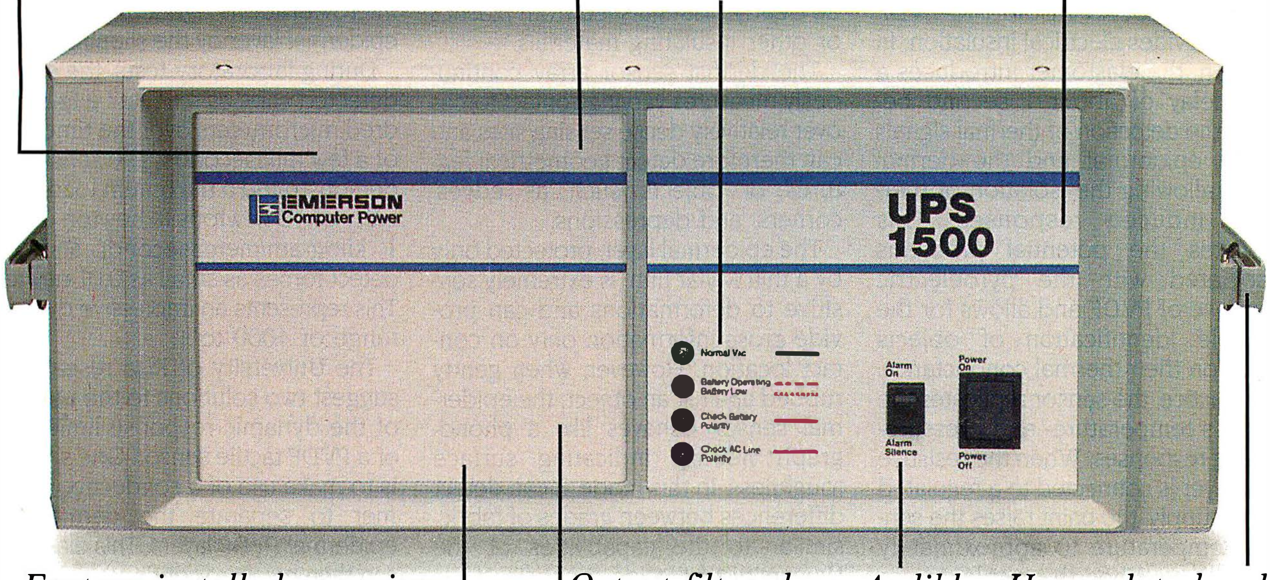
One of their designs attempts to reproduce the sensing properties of the human fingertip. The sensor consists of an outer *epidermal* layer and an inner *dermal* layer (see figure 5), each of which performs distinct sensing functions. The epidermal layer consists of a 40-micrometer-thick film of PVDF protected by a thin Mylar sheet.

Electrodes on the top and bottom of the epidermal PVDF film carry off any electrical charge to signal processing equipment. The underside of the PVDF layer is covered with a resistive paint and is backed by an elastomer layer. A 110-micrometer-thick PVDF film is attached to the underside of the elastomer layer. The lower PVDF layer serves as the dermal sensor and is bonded to a circuit board containing an 8 by 16 array of circular electrodes, spaced on 3-mm centers.

Any charge developed in the dermal PVDF layer is discretely measured by the closest electrode sites. The signals from the electrodes are consecutively scanned, fed into a charge amplification device, and measured. This design allows the sensor to measure gross pressure deformations in the epidermal layer and more highly resolved and localized defor-

(continued)

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mations in the dermal layer.

The overall sensor dimension is approximately 1 by 2 inches. The elastomer layer between the two PVDF layers provides electrical insulation. In addition, the elastomer introduces a time delay of about 1 second between the detection of thermal signals in the epidermal and the dermal layers, allowing the isolation of thermally induced responses. This alleviates the potential problems associated with the pyroelectric response of PVDF and allows for the possible identification of objects based on their thermal conductance.

In practice, the sensor replicates the human's temperature- and pressure-sensing responses. When the resistive paint layer is connected to a regulated power supply, the paint raises the sensor's temperature to approximately 37° Celsius. When the tactile sensor touches an object, heat flows from the resistive layer through the PVDF epidermal sensor to the object. The rate of heat flow depends on the thermal properties of the object being touched. This allows metals, which have a high thermal conductivity, to be clearly distinguished from plastics or other insulating materials.

The dermal sensor array continuously measures varying contact forces over relatively dense sensing sites and can therefore detect geometrical features of objects such as edges, corners, and depressions.

The epidermal layer, protected only by a thin Mylar film, is extremely sensitive to deformations and can provide gross information only on contact location. However, when gently rubbed against an object, the epidermal sensor behaves like a phonograph needle, indicating surface roughness. In this mode, it can detect differences between grades of fabric, similar to the capabilities of the University of Florida sensor.

When pressed against an object and then released, the combined signals detected by the epidermal and dermal layers provide information on object hardness. When installed in a mechanical gripper, the sensor can determine object slippage based on microvibrations generated in the epidermal layer by the slipping object.

During laboratory tests, the sensor detected slips as small as a few hundred micrometers over the time span of a few milliseconds. The sensor has demonstrated a maximum load capability of 40 newtons (a newton equals 1 kilogram/meter/second) and can detect forces as small as 0.01 newton. This represents an impressive dynamic range of 4000 to 1.

The University of Pisa researchers suggest two solutions to the problem of the dynamic response limitations of a PVDF tactile sensor. One solution is to make use of a conductive elastomer to separate the dermal and epidermal PVDF layers. This elastomer can then measure continuous pressure in the same way as the conductive elastomer sensors described earlier.

Another solution is to send sound pulses from the lower to the upper PVDF layers. By measuring any differences in the travel time of the waves from the lower to the upper layer, the amount of compression can be determined and the pressure indirectly inferred. The University of Pisa sensor appears to offer great promise as a general-purpose tactile sensor combining many functions into a single device.

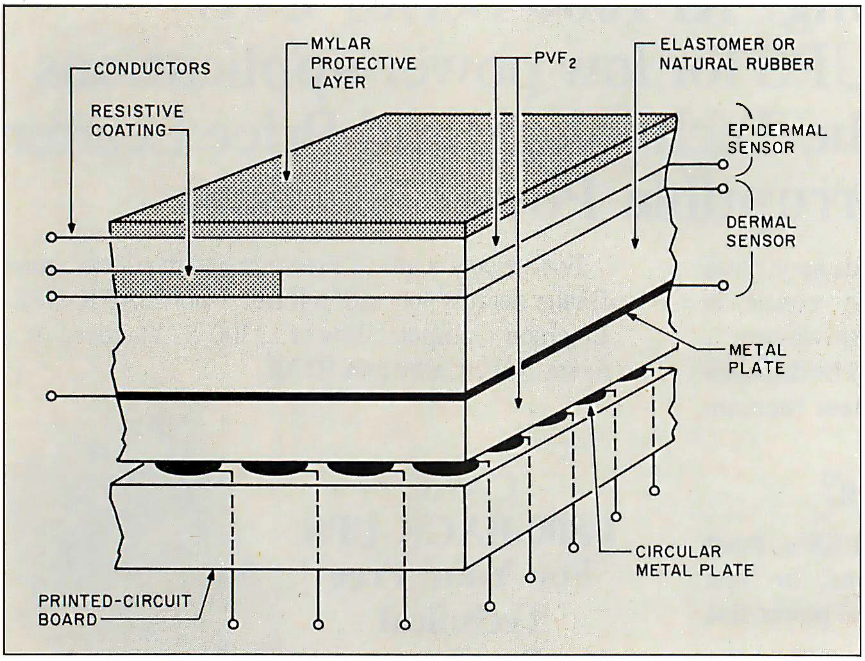
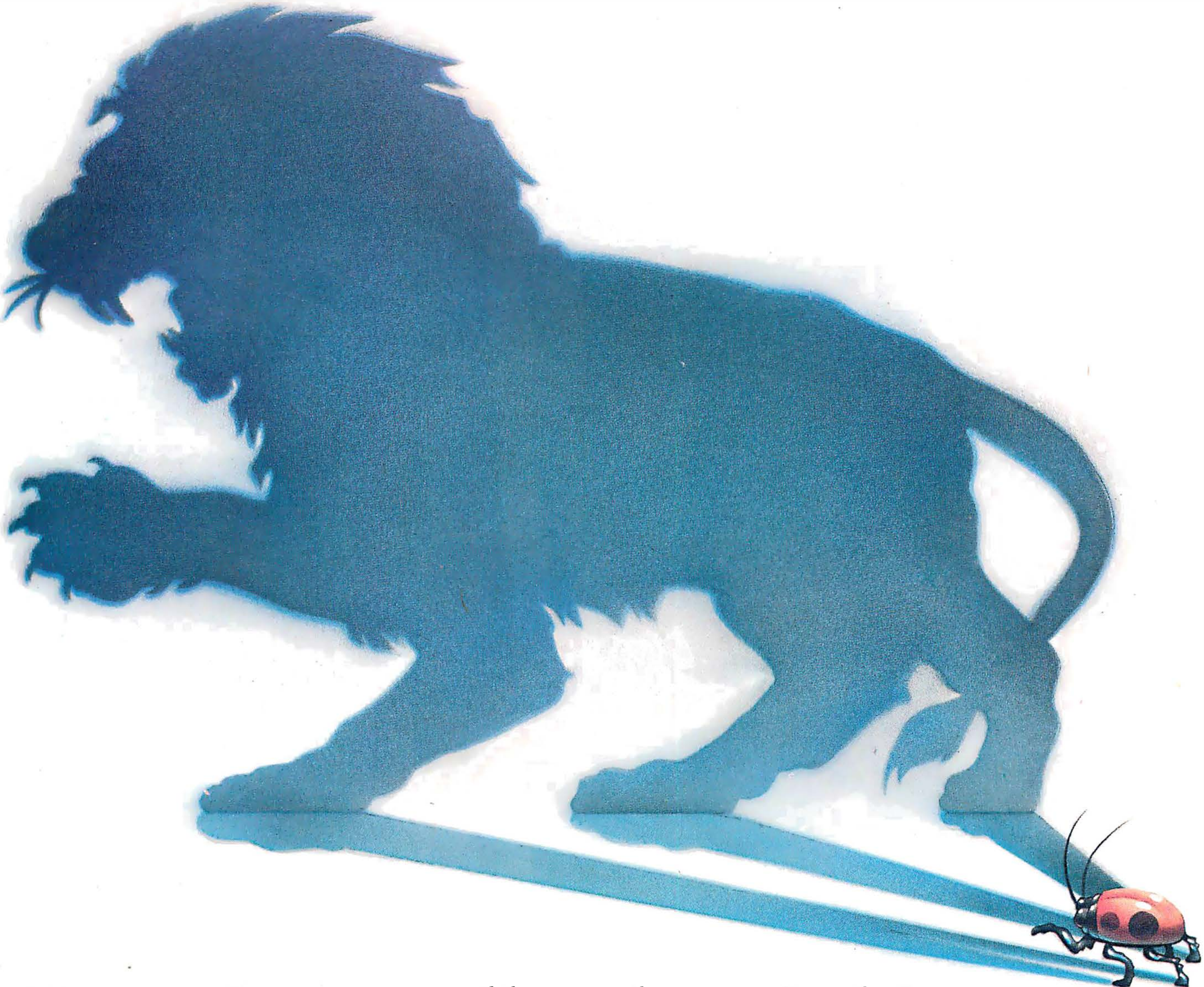


Figure 5: *A skinlike tactile sensor with an outer (epidermal) layer and an inner (dermal) layer. The sensor was developed at the E. Piaggio Center of the University of Pisa and at the Institute of Clinical Physiology of the Italian National Research Council. This figure is reprinted with permission of the IEEE and appeared in "Tactile Sensors and the Gripping Challenge" by Dr. Paolo Dario and Dr. Danilo De Rossi* (IEEE Spectrum, *August* 1985).

Conclusion

There are many approaches to tactile sensing that I have not covered. These include the use of ultrasound, magnetic induction, electrotopography, and other intriguing techniques. I have tried to identify many of the major concepts and stimulate ideas for future approaches.

The robotics designer should be aware of the trade-offs involved between the spatial density of a sensor array and its resultant computational requirements. Higher resolutions often require much greater data-processing capability. Also, it is important to remember that the intended use of the sensor plays a major role in its design. ■



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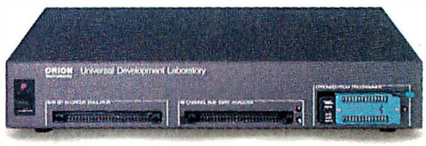
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MULTIPLE ROBOTIC MANIPULATORS

BY J. SCOTT HAWKER, R. N. NAGEL, RICHARD ROBERTS, AND NICHOLAS G. ODREY

Designing a task-oriented control system for multiple manipulators

WHEN CONFRONTED WITH issues related to robots, the average person generally envisions a device or system that is humanlike in form and possesses some human attributes. Robotic reality is quite different from this perception. Robots are generally not human in form and rarely possess human qualities or attributes. Robots in the industrial environment are, for the most part, very simple devices performing simple tasks. To date, few robots have been integrated to work together on the same task or even in the same workspace.

It appears on the surface that coordinating two robots is not a difficult assignment. This is not the case. To more fully appreciate the potential difficulties with coordinated performance, consider the requirements for holding a pencil or cylindrical object between the tips of two index fingers. This action requires that the two fingers exert a force on each end of the pencil or cylinder. These forces must support the weight of the pencil (see figure 1a). At the same time, the forces must be limited so they don't damage either the pencil or, from the human standpoint, the fingertips. This type of behavior clearly requires force sensors and coordinated control between the two fingertips.

Now let's add more complexity to the assignment. Consider the problem of holding one fingertip poised in space (fixing one end of the pencil) while moving the other fingertip in a circular path, causing the other end of the pencil to follow (figure 1b). A slightly more ambitious assignment would be moving both ends in circular paths simultaneously (figure 1c). Then, while rotating both pencil tips in circular paths, move or translate the pencil through space (figure 1d).

The three motions described require that the forces between the fingers and the positions of the fingertips be carefully controlled. We recommend that you attempt these motions (as shown in figures 1a through 1d) to appreciate the subtleties involved in moving the pencil through its paces.

It becomes apparent that a means of monitoring and controlling the applied force is needed. In addition, a means for setting, monitoring, and controlling the paths of the pencil's end points is required. Communica-

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R. N. Nagel holds B.S. and M.S. degrees in mathematics from Stevens Institute of Technology and a Ph.D. in computer science from the University of Maryland. Dr. Nagel is the director of the Institute for Robotics at Lehigh University.

Richard Roberts holds a Ph.D. in mechanical engineering from Lehigh University. Professor Roberts is an expert in the areas of machine design and failure analysis.

Nicholas G. Odrey holds B.S. and M.S. degrees in aerospace engineering and a Ph.D. in industrial engineering. Dr. Odrey is the director of the Robotics Laboratory of the Institute for Robotics at Lehigh University.

All of the above authors may be contacted at the Institute for Robotics, Lehigh University, 200 West Packer Ave., Bethlehem, PA 18015.

tion channels and a minimum level of intelligence are required so that the proverbial left hand knows what the right hand is doing.

In addition to these requirements, the benefits of practice should have become obvious. As the tasks are repeated and the fingertips become more skilled, the coordinated motion becomes easier. This last feature, the ability to improve performance through trial, is especially important if a robot is to be a truly flexible, adaptable element in a factory environment.

Dual-Arm Structure

Researchers at the Institute for Robotics at Lehigh University are now studying the philosophy and implementation of high-level, task-oriented control of dual-arm robots, as well as the design and low-level control of robotic arms. The dual-arm robot being described was designed as a research system capable of providing a variety of issues related to coordinated control of two or more robotic arms.

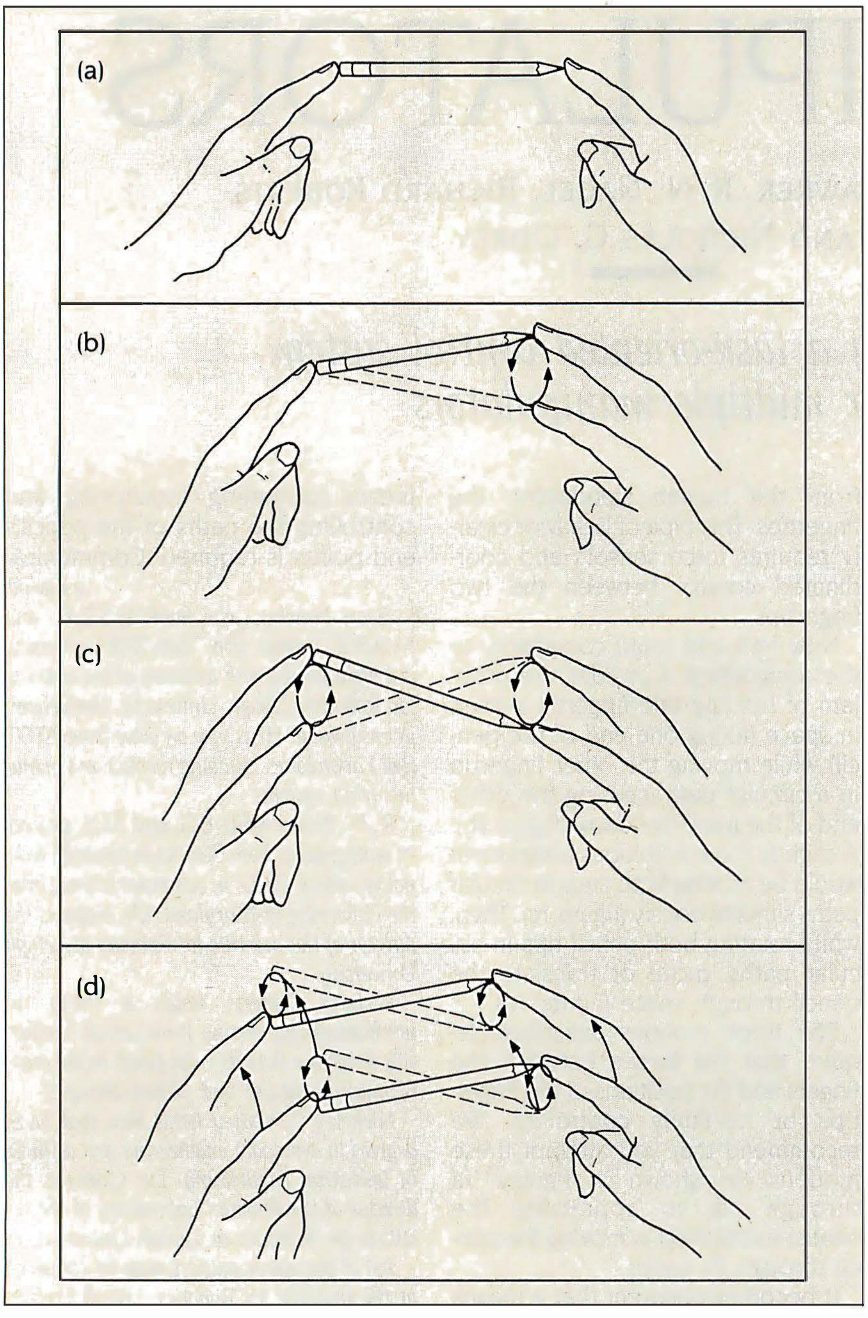


Figure 1: *The actions of two hands rotating a pencil and moving it through space.*

As we made individual design decisions, we always biased them to provide as challenging a set of problems as possible for the researcher. The dual-arm robot currently being constructed at Lehigh University consists of two movable robot arms attached to a rigid base. Each arm possesses seven degrees of freedom: three translational and four rotational. Figure 2 shows the structure and the various degrees of freedom of one of these arms.

Each arm is attached to the rigid base in a way that allows the attachment points to move with two degrees of freedom in a fixed vertical plane. The range of travel for coordinate axes is as follows: Translational axis 1 is 7 feet, translational axis 2 is 3 feet, and translational axis 3 is approximately 1½ feet. When fully extended, the robot hand can reach 55 inches from the vertical plane represented by coordinate translational axes 1 and 2.

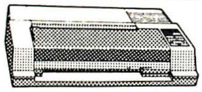
The precise limitations of the angular travel of rotational coordinates 1, 2, and 3 are not known but are believed to be in the range of plus or minus 90 degrees. Rotational axis 4 can provide a full 360 degrees of rotation. With the ranges of travel noted for the translational and rotational axes of the two arms, a large work envelope can be addressed. This should provide ample space to confront the two arms with tasks that require coordinated motion.

Implementation

We chose aluminum as the material for construction of the robot arms in order to minimize the weight of the arms and reduce the requirements of the driving actuator motors for the system (we designed each arm to han-

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dle a total load of 5 pounds).

Both stepper motors and servo motors are used for driving the robot arms. The three translational axes and the first rotational degree of freedom are powered by stepper motors. The drivers for the remaining three rotational degrees of freedom and the motor that actuates the hand are servo motors.

We based the decision to mix the types of motors on size and power requirements, delivery schedules, and cost. In addition to these factors (and probably just as important) was the desire to provide the designers of the low-level controls with the different challenges presented by each motor type. All of the stepper and servo motors are equipped with position sensors so that the motions of the arms can be measured. In addition to the positional sensors, each hand will be equipped with a force sensor so that the forces exerted by the hand can also be measured.

Controlling two arms to cooperate in accomplishing one task is more complex than controlling two arms to accomplish two independent tasks. Nevertheless, it is very important that adequate, independent, single-arm control mechanisms be in place for each of the two arms so that their motions and applied forces can be controlled within the motion constraints specified. These single-arm controllers can then be extended and coupled to form an integrated dual-arm controller.

Since dual-arm control is an extension of single-arm control, we will first describe the common approaches to and requirements of single-arm control. We will highlight the single-arm control problems that are not adequately solved and will assume that answers to these problems will be applicable to dual-arm control.

Single-Arm Control

In order to provide a clear understanding of the goals of single-arm control, our discussion will consider a robotic arm to be very much like a human arm: a series of connected mechanical links or "bones" that allow the end of the last link (the end effector or "hand") to be placed at some position and orientation in space. The energy that causes the motion of the arm comes from actuators or "muscles" that drive the motion of each mechanical "joint" to achieve the desired pose, motion, or force of the end effector.

A control computer is normally used to generate the particular ac-

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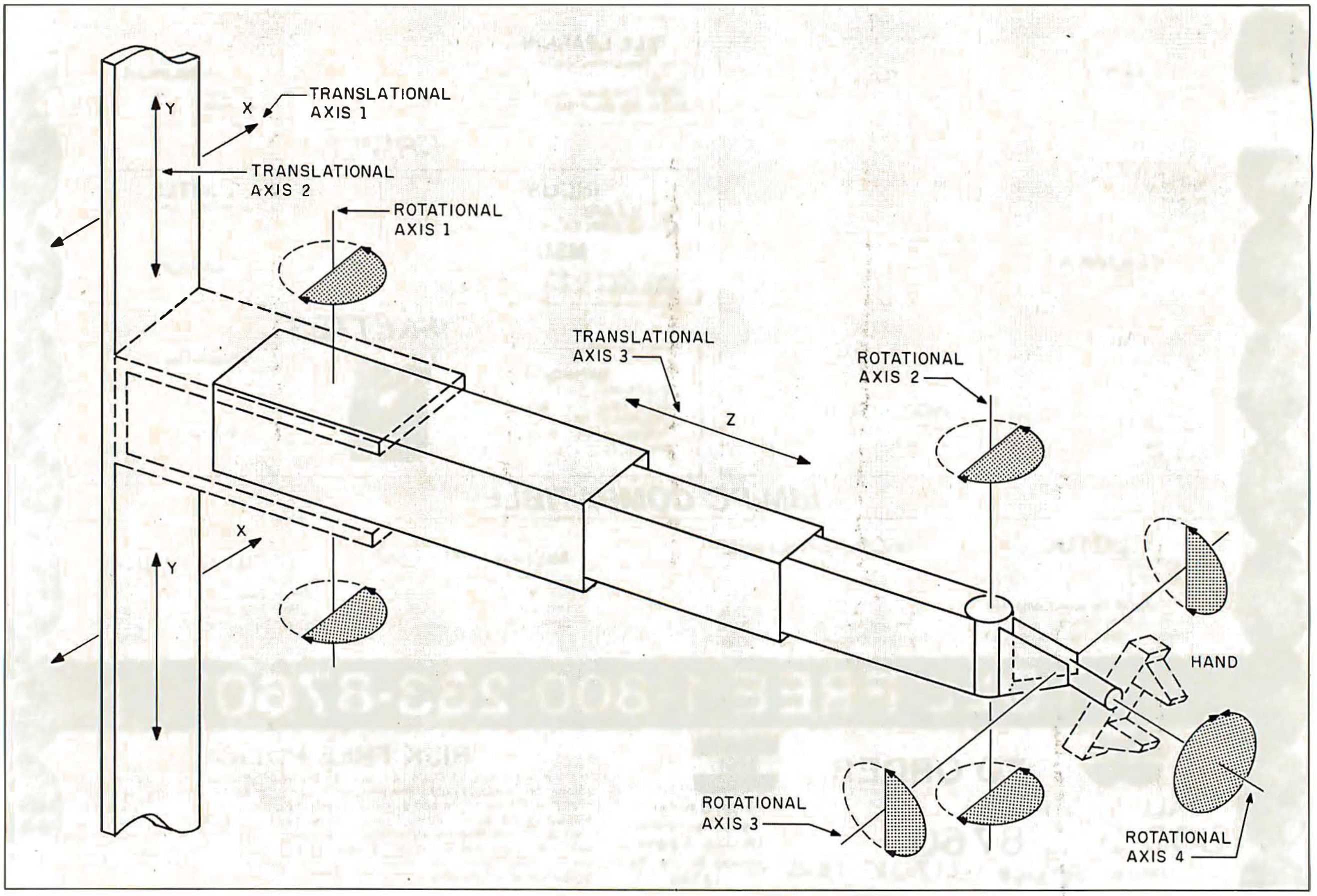


Figure 2: *A schematic representation of Lehigh University's robot arm showing the three translational axes of movement and the four rotational axes of movement.*

tuator drive signals that coordinate the motion of the joints and linkages of a single-arm manipulator. For example, raising the end effector may be achieved by "shoulder" motion, "elbow" motion, or both. This kind of control, which corresponds loosely to the basic motor skills of the human brain, is called "low-level" control in that it is automatic. (Most people don't concentrate on which muscles they have to move to lift a pencil.) Much more effort is expended on planning and executing the overall task (the high-level control), while the low-level control operation is assumed to be available and is essentially ignored.

All the planning, execution monitoring, and low-level control suggests that there is far more to a single robotic arm than a collection of linkages, actuators, and basic motor control that mimics the human arm. This is indeed true. For example, the end-effector "hand" is usually designed for specific tasks. A welding tool is used on a welding arm, a viselike gripper or humanlike hand on an assembly arm, and a paint sprayer on a painting arm. The operation of the end-effector devices must also be controlled in coordination with the motions of the end effector, as determined by the low-level controlled motion of the link actuators.

It is obvious then that the high-level control that dictates to the low-level control the pose of the arm end effector must also tell the end effector what to do once it is there. The goal of the high-level computer is to determine the particular sequence of link motions and end-effector operations that accomplish a given task and then drive the low-level control that generates the arm and end-effector actuator drive signals to achieve the task motions and operations.

Throughout the performance of the task, the task execution must be monitored through sensors not only to assure that the motions and operations are as expected but also to adjust the actuator drive to correct any sensed errors. Such closed-loop or feedback control is used at both the low and high levels of control.

In order to achieve real-time closed-loop control for a system as complex as an autonomous robot, data must be gathered (through sensing transducers), processed, and monitored to update the parameters of the control and decision algorithms before they are executed. The real-time aspect is required so that error feedback can provide input corrections quickly enough to reduce errors before they become too large. The more variable the working environment, the more data must be gathered, and the more quickly unexpected changes might occur, the more quickly this data must

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be processed and fed back to the control input.

Stability

Complex coupled systems such as single- or dual-arm robots have the potential for unbounded or uncontrolled behavior (instability) in certain ranges of operation. These regions are usually characterized by constraints on allowed velocities and accelerations or by regions of the workspace that are less precisely controlled than other regions. The control system must be designed to locate and avoid, or otherwise accommodate, these regions of operation without adversely affecting the flexibility in the range of operation.

Most commercial control systems simplify the control issues by placing limits on the overall velocities and accelerations and therefore do not allow the robot to perform to its maximum capabilities throughout the workspace.

As the above discussion indicates, the more flexibility required in a robotic application, the greater the number of variables that must be controlled simultaneously. State-of-the-art systems are typified by the extensive use of fixtures to reduce the number of variables to a manageable level. Unfortunately, such structures also reduce the flexibility of a system in accommodating new tasks or unexpected difficulties.

This use of rigid structures is often attributable to the lack of availability of a broad range of sensors and low-cost control computers, and the difficulty and cost of overall integration into a sensory feedback, real-time control system. The development of the more complex dual-arm robotic systems must address these issues more directly, without imposing rigid structures by "engineering away" problems.

Control Levels

Researchers at the National Bureau of Standards (NBS) have developed a philosophy for designing and implementing real-time, hierarchically distributed, sensory-control systems incorporating robotic arms, machine tools, and other manufacturing devices.

This philosophy has been successfully demonstrated repeatedly and has recently been applied to a form of dual-arm control. Because of this demonstrated success, the dual-arm research at Lehigh is based on the NBS philosophy of distributed hierarchical control.

We have chosen to describe the portion of the control that *achieves* the desired motions as "low-level control" and the portion that *determines* the motions desired for a task as "high-level control." This dictates the following interpretation of the present state of research in robotic arm control.

Closed-loop sensing and control algorithms now exist that allow precise and stable control of the position and orientation of the end effector of an arm, and techniques for more general velocity and force control are well under development at many research laboratories. Low-level control mechanisms now or will soon exist that, when given the desired trajectory (position versus time) of the end effector, will provide the desired motion.

The end effector itself is typically a very simple special-purpose tool for which low-level control is also readily available. However, more general-purpose end effectors, such as humanlike hands that can grasp a wide variety of objects or hand tools, are slow in development due to many of the same problems of dual-arm control.

Much of the research on high-level, task-oriented control is focused on the planning aspects associated with various tasks. The planning aspects are concerned with how to automati-

(continued)

cally generate the trajectory path of an arm carrying an object so that it does not collide with other objects in the workspace, or how to determine the best grasp location and force for a particular object based on data represented in a computer-aided design (CAD) model of the object.

Perhaps more important, artificial intelligence researchers are searching for algorithms and heuristics for the automatic decomposition of the steps of a task into a sequence of simpler subtasks that are already implemented. Artificial intelligence researchers and others are searching for robust techniques for executing the task steps in the presence of uncertainties and unexpected changes in the work environment.

Visible results of research on high-level control systems include a number of human-oriented graphical programming and simulation systems for robot motion programming and the development of high-level robot programming languages. These languages have, in some cases, been modeled after popular structured programming languages (e.g., Pascal, APL, and FORTH).

Other available results include the development and application of a number of techniques for visual image processing and image understanding. Methods for integrating these and other sensory-perception techniques into an autonomous, intelligent control system are under intense, although slow, study. Our plan is that the dual-arm research project will provide a flexible and powerful test bed for accelerating the development of robust, generic solutions to high-level control problems.

Dual-Arm Control

There are research challenges in dual-arm control at both the low level (how to achieve the desired motions in real time) and the high level (how to determine the desired motions to achieve a task). The challenges at the low level derive from the need for coordinated control of two arms in real time, as well as a data-communications technique that supports the distribution of commands and data among the distributed control elements of the two arms.

Many single-arm systems can bypass these requirements because the control and sensing algorithms are simple enough to allow a single computer to perform all tasks in real time. With dual-arm systems, the number of control and sensing procedures is more than double that of single-arm systems, so the sensing and control functions must be distributed among a number of physically distinct and heterogeneous computers.

At the high level, the problems associated with single-arm task planning and execution are magnified by the fact that the job tasks must be partitioned among two arms, but the task partitioning must be coordinated in such a way that the high-level task is accomplished correctly. Algorithms for planning and monitoring must be modified from the domain of the single arm to the more general dual-arm arena.

Just as general techniques for the distribution of function and data have proved elusive in the world of distributed and parallel computing, so too have general techniques for distributed control of robots.

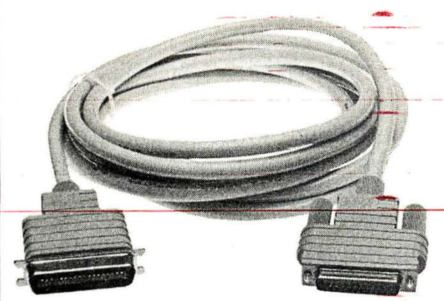
The NBS approach is to partition the sensory processing, world modeling (expectations), and control functions. The control functions are decomposed into hierarchically structured, limited-scope modules. This same approach has proved useful in the preliminary study and research of dual-arm systems at Lehigh University.

It seems natural to think of a dual-arm robot as two independent, low-level, single-arm controllers directed by a third (higher-level) controller that coordinates and synchronizes the arms (see figure 3). This approach, however, does not allow the arms to work together in a tightly coupled operation such as manipulating the pencil.

The role of the high-level coordinating controller is needed, but the low-level single-arm controllers must also be integrated, for example, to

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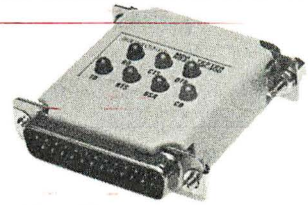


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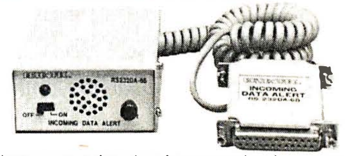
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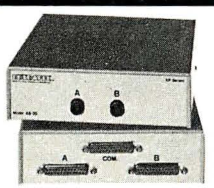
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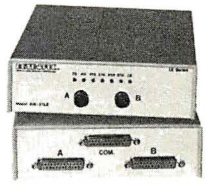


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allow the forces felt by one arm to directly modify the forces applied by the other arm. This results in the conceptual control architecture shown in figure 3, integrated into the overall system architecture shown in figure 4.

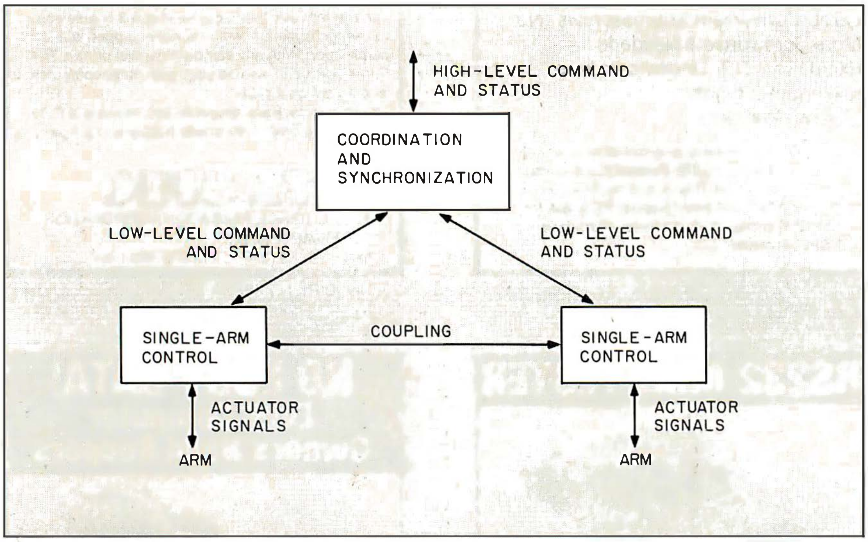


Figure 3: *Simplified dual-arm control hierarchy showing low-level and high-level functions.*

Note in figure 4 that the low levels are coupled directly in the control portion and also indirectly through the model.

Distribution of Function

Physical implementation of the conceptual system models shown in figures 3 and 4 requires more explicit definition of the distribution of function and data between low- and high-level control and between the individual low-level controls. For example, consider which element is responsible for avoiding collisions (i.e., the individual arm controllers or the high-level coordinating controller).

It seems that the collision-avoidance function itself should be split and the subfunctions distributed. Similarly, how does the grasp planning of one arm consider the fact that an object is to be handed to another arm whose grasp requirements must also be accommodated? The laboratory system

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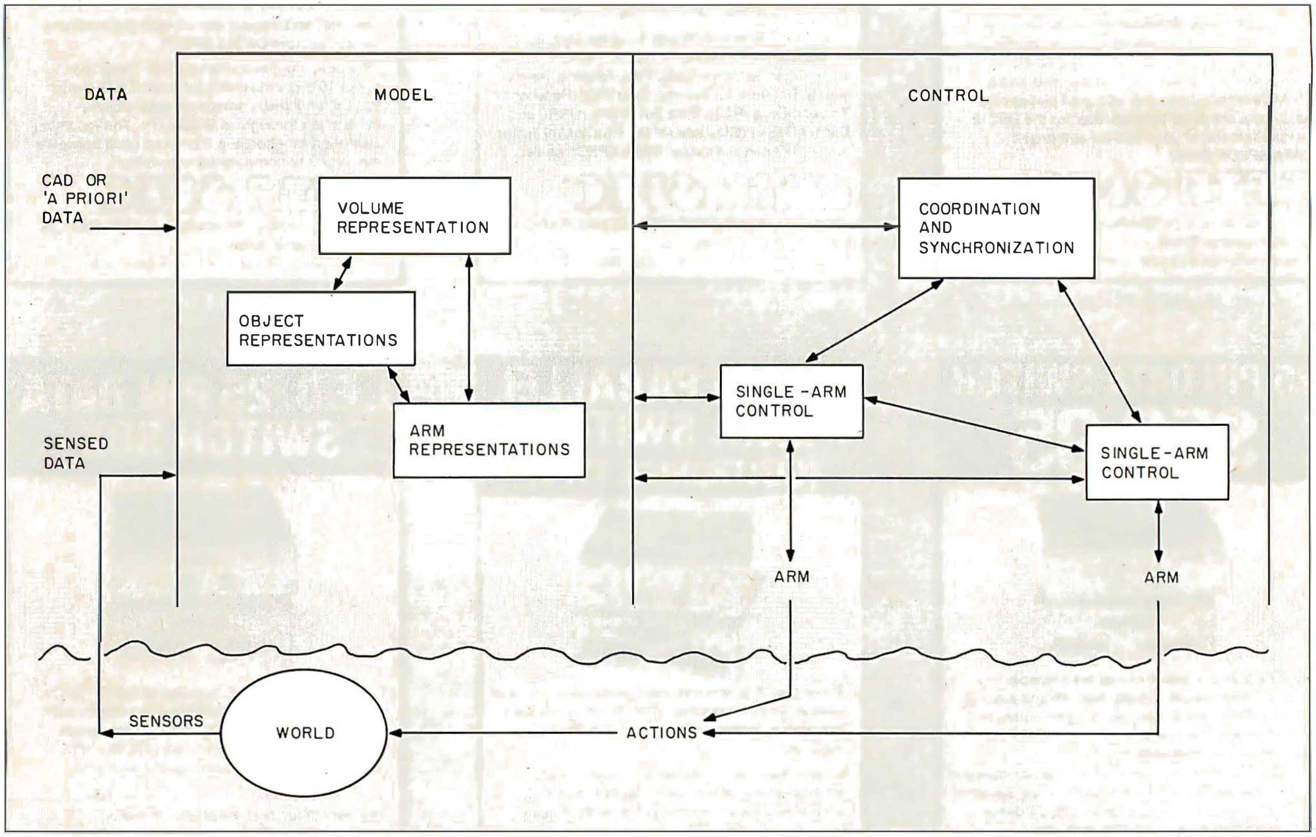


Figure 4: *Overall system control hierarchy of a dual-arm robot, showing the relationship between the external world, the actual control, and the intrinsic model used by the system.*

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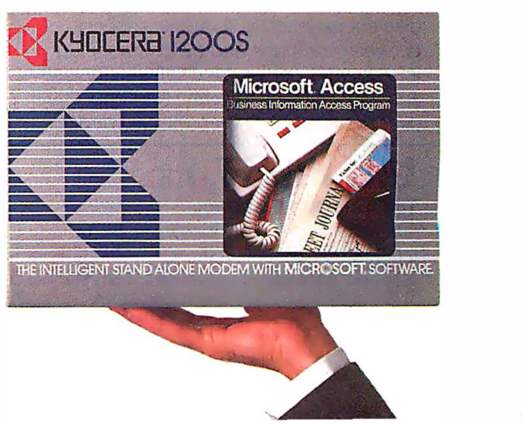


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currently under development will allow various alternatives to such issues to be quickly and easily explored.

Lehigh University researchers have designed a control structure for complex dual-arm operations, and initial research has progressed in two areas: pick-and-place operations with two arms that have overlapping workspaces and the design of task-planning algorithms to allow the interchange of objects between arms (i.e., end effectors) in free space.

The existence of overlapping workspaces has led to the development of algorithms for collision avoidance that consider two moving arms. The planning of free-space object interchange takes into consideration the relative locations of the arms, objects to be manipulated, and object destinations, and assigns arm subtasks based on these considerations within the confines of workspace areas accessible to the arms.

COORDINATED-CONTROL RESEARCH

Lehigh University researchers believe that a distributed control and communications system must be implemented and that high-level control algorithms must be developed to accommodate the increased number of variables and capabilities of dual-arm robots. They have also noted that single-arm low- and high-level control techniques may not be directly applicable due to the increased complexity of dual-arm implementations.

Lehigh's research team has developed a plan that will begin to uncover the requirements and implementations of dual-arm and more general-purpose multidevice manufacturing systems. The first step in the study of multidevice systems is to obtain a clear understanding of how complex tasks are decomposed into simpler subtask "primitives." This understanding of task decomposition must be accompanied by an in-depth knowledge of how manufacturing systems are combined to achieve a particular task. We must understand the system composition that supports the task decomposition.

We are approaching this problem in two ways. First, we are identifying and developing mathematical system analysis (decomposition) and synthesis (composition) tools that allow theoretical modeling and study of manufacturing systems. Second, we are developing a flexible system-implementation strategy that follows the structure of the mathematical tools.

This strategy includes modular design with rules for integrating the modules into a system. Clearly defined, functionally bounded modules with clearly defined data and control interfaces must be developed.

The dual-arm laboratory system under development is the first step toward this system-building understanding. It will allow us to study such questions as "How can two arms be controlled to cooperate in lifting a load heavier than one arm can handle alone?" or "How can two arms be controlled to manipulate the ends of a pencil without dropping or breaking the pencil?"

More fundamental to an autonomous flexible operation, perhaps, is obtaining answers to such questions as "What general task-decomposition techniques are needed to consider the increased capability of two arms, rather than simply considering two independent arms?" That is, "What does parallelism provide that distinguishes it from overlapping sequential control?" We believe the answer lies in the term "coordination," which could be interpreted as "dependent" overlapped sequential control.

Our research is aimed at understanding and controlling this dependency to achieve coordination. Our short-term goal is to develop a

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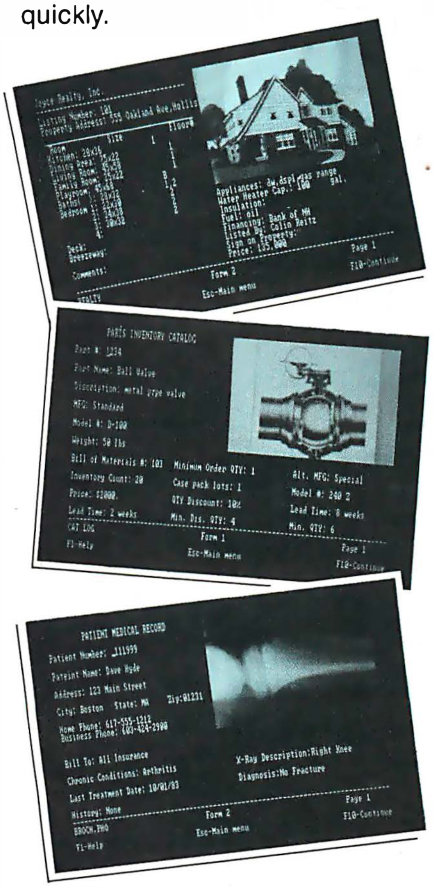
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The Lehigh arm has seven degrees of freedom.

mathematical theory of manufacturing-system building and to develop implementations that realize these theoretical systems. The long-term goal is to develop a general approach to classification of the capabilities of manufacturing devices and then extend the dual-arm analysis and synthesis philosophies to allow synthesis of multiclass machine work-cell tasks.

The ultimate goal of this and related research is to develop the mathematical tools and system-implementation techniques needed to automatically synthesize an entire facility's production schedule in direct response to customer demand, even when (especially when) the customer demands only one custom part. This implies that, with only a customer's description of the part, the facility resources are automatically allocated and control programs are generated (synthesized) and executed, resulting in the economical production of that one custom part.

CONCLUSIONS

In order to implement a manufacturing system with the flexibility required for future production, we must first develop a fundamental understanding of manufacturing-device coordination in conjunction with the necessary system analysis and synthesis tools to achieve this device coordination.

The direct results of dual-arm robotic research will be readily applicable to many manufacturing tasks. More important, the overall knowledge obtained by studying the dual-arm system will be applied toward developing a general theory of structural analysis and synthesis for flexible, modular manufacturing systems.

We have begun the ambitious undertaking of developing such a general theory. To date, Lehigh has implemented a sensory-control and modeling system based on the NBS philosophy of hierarchical real-time system control. In addition, we have implemented a data-communications network and distributed the low-level and high-level control of a dual-arm cooperating pick-and-place robot, and we are in the process of duplicating this control for the pair of Lehigh-designed, dual seven-degrees-of-freedom arms described above.

Many of the high-level control strategies are in the feasibility phase of development and thus offer only rudimentary capabilities. They were developed to demonstrate the cooperation of two arms in an overlapping workspace for the "simple" tasks involved in pick-and-place operations. The implementations allow more general study of the sophistication required of the high-level coordination mechanisms needed for flexible, autonomous, multidevice manufacturing systems. ■

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AUTONOMOUS ROBOT NAVIGATION

BY CHARLES JORGENSEN, WILLIAM HAMEL, AND CHARLES WEISBIN

Teaching robots to look before they leap

MOST COMMERCIAL robotic systems depend heavily on the fact that their job environments are well known and change only in prescribed ways. Generally, when navigation is required, the environment rather than the robot is designed to accommodate movement. We can keep paths of movement open, preposition assembly lines, preplace parts, and reduce variations and unknown factors.

When we relax such restrictions, however, we must increase the robot's capabilities to compensate for unpredictability in the environment. Thus, the first step toward generalized mobility is to add sensors to provide data so that the environment and the internal state of the robot can be determined prior to any decisions. In this instance, because the spatial relationships between the robot and the world are no longer predetermined, two questions immediately arise. First, what does the world map look like? This requires some form of sensor mapping. Second, where is the robot at any given moment relative to that world? This is called self-location.

Because both robot position and environment may change in real-world problems, an advanced autonomous robot must be capable of answering both questions. Until recently, experiments in autonomous navigation have focused primarily on robot environment mapmaking rather than on the self-location problem. As a result, even though the experimental environment could change in minor ways, it usually contained a fixed reference point that the robot sensors could detect and use to calculate self-location. For example, self-location has been calculated by homing on a single point such as a radio source, following a path like a magnetic floor tape, using triangulation on infrared emitters (reference 1), or sighting specially constructed optical landmarks.

Commercial applications such as in-plant mail delivery have used such systems to a limited extent, but they are not practical for unplanned situations like military land-vehicle operation or emergency repair of nuclear power plant components. For these situations, a robot needs to construct temporary references instead of relying on known references. An example of a temporary reference is using a landmark such as a tall building to orient streets and buildings.

THE FIND-PATH PROBLEM

Once a robot has determined a reference point and used its sensors to generate a map of the external environment, it must select control algorithms associated with movement. That is, it must find a path to its goal.

The so-called find-path problem, which has been carefully studied in robotics, can be stated as follows: Given an object with an initial location and a set of obstacles whose spatial location is known, find a continuous path from the initial position to the goal that avoids collision with obstacles along the way. Researchers

(continued)

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have proposed a variety of approaches to solving this problem.

One approach, called the configuration-space method by Lozano-Perez (reference 2), divides a navigation space into zones that the reference point of a robot can occupy without the robot colliding with any obstacles. Paths are then defined for the reference point that makes maximum use of the open area between the reference point and a specified goal. For example, to define the configuration space, Moravec's Rover (reference 3) bounded all obstacles with circles that were enlarged to assure clearances for the robot edges. Paths were then calculated as tangents to these circles. In the context of robot manipulators, Udupa (reference 4) chose to bound the obstacles with complex polyhedra.

Other approaches involve either local or global navigation strategies. Local navigation deals with immediate problems of obstacle avoidance, whereas global navigation considers larger regional information like the plan of a building or long-term goals. For example, Crowley (reference 5) described global path planning in terms of previously stored networks of places. He defined global navigation as traversals along "legal highways" in known areas, with local movement based primarily on avoidance procedures using sensors.

Recently, there has been an interest in merging exploration and learning. Learning has been considered in other aspects of robotics, such as manipulator movement (reference 6), but has only recently been applied to navigation control (reference 7). The many factors involved in exploratory robot navigation make it useful to have a conceptual framework to discuss the points. We will now consider one such framework, based on some well-known human explorers.

EXPLORATION

Navigation in unknown territory implies that a robot is going to encounter unexpected situations. The robot will have to surmount problems such as how to avoid obstacles. There will also be serendipitous discoveries that can be exploited. Such situations are common for all explorers, whether mortals or machines. To clarify the issues involved, let us consider three well-known explorers and their labors and how they relate to autonomous robot navigation.

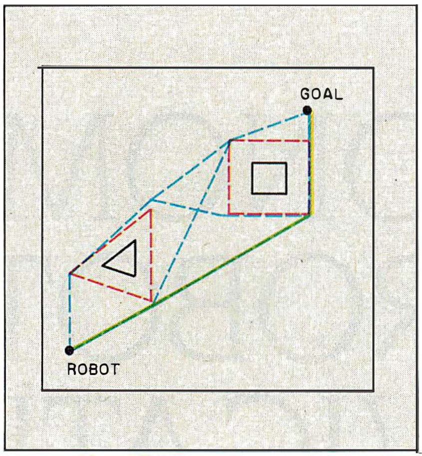


Figure 1: *A simple robotic obstacle-course floor map. The red lines represent the bloomed obstacle diameters, blue indicates projected path lines, and green identifies the shortest path.*

We will begin by comparing a mobile robot to Ferdinand Magellan, the British cartographer whose map-making consolidated a disordered 16th century world into sets of well-ordered countries and coasts. Next, we will consider the less structured world of Christopher Columbus navigating toward unknown territory. Finally, we will examine the mythical hero Ulysses as he contends with the whims of the gods who change his world and throw dangers in his path.

Our explorer will be HERMIES II, a small mobile robot at Oak Ridge National Laboratory, as he navigates around the laboratory at the Center for Engineering Systems Advanced Research (CESAR).

MAGELLAN

Magellan was interested primarily in the accurate circumnavigation of the world in which he traveled. He therefore prepared detailed maps from bits and pieces of geographic information gathered from many sources. He synthesized this information into a spatial map that reduced the three-dimensional real world into scaled distances between objects characterized in two-dimensional Cartesian projections.

When used by an experienced navigator, the maps of Magellan permitted the accurate selection of proper headings and destination points and minimized travel distances. In the same way that Magellan organized the world into maps and used that information for path planning, a robot must be able to use spatial maps of the environment to select destinations and minimize the expenditure of resources when seeking goals.

At the Magellan level, we assume that information about the spatial characteristics of the environment is suitably stored in computer memory and accessible to the robot-control algorithms. Given known obstacle locations that make straight-line traversal impossible, the robot's task becomes one of finding the best path to a goal destination. If necessary, the robot may need to turn and maneuver in tight spaces, dead-end corridors, or mazes. Such situations often occur in real-world environments such as large industrial plants or buildings.

Figure 1 shows a sample room with two obstacles placed between a robot and a goal point. The dark borders of the obstacles represent a two-dimensional projection of the three-dimensional object shapes. Because the exact locations of obstacles are known, navigation could be performed as follows: A line is projected from the robot to the goal. If the path is clear, the robot uses the line to calculate an angle of turn and travel distance using the Pythagorean theorem.

However, such a simple algorithm could result in problems. For one thing, we have made no allowance for the width of the robot, and it may collide with edges of obstacles. Consequently, a robust algorithm must take into account required clearances due to all sources of potential imprecision. Second, if a straight line is not reasonable, the robot requires a procedure

(continued)

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The piano-mover problem considers both rotation and translation.

for obtaining other paths and selecting one from among the intermediate choices, much as a traveler would select intermediate stops on the way to a destination. This kind of situation is an instance of the find-path problem.

One way to implement a find-path algorithm is shown in figure 1. Here, the known boundaries of the obstacles are enlarged ("bloomed") by an amount equal to one-half the diameter of the robot plus an extra amount for uncertainty associated with the robot's actual position. At the same time, the robot is mathematically shrunk to a single point. If some object obstructs a straight-line path to the goal, hypothetical lines are drawn from that point to each of the vertices (edges) of the expanded obstacles in direct line of sight of the robot. From each of those points, new lines are drawn to each vertex of the obstacles in their line of sight, and so on, until a line of sight from some vertex to the goal has been obtained.

All paths from the robot's current position to the goal are converted into a graph of nodes and edges where each edge is a path segment. Finding the best path consists of examining path lengths from the start node to the finish and selecting the shortest sequence. Optimal solutions for such find-path problems have been developed that permit the answer to be obtained very efficiently, such as the A* algorithm used in the artificial intelligence community for the search of decision graphs. Moravec used the approach of projecting three-dimensional shapes onto two-dimensional surfaces and calculating tangential paths as a method of navigation planning for the Mars Rover.

When the available movement corridors are very narrow, the robot needs more complex algorithms to calculate its rotations. This class of path planning has been called the "piano-mover problem" (reference 8).

In the simple find-path problem above, we treated the robot as a point rather than a polygonal body with unequal dimensions and appendages into the navigation space. Such an approach will work if there is plenty of maneuvering room. In the case of the piano-mover problem, the corridors the robot will traverse may narrow so that the robot must rotate to squeeze through clearances the way a piano mover must make turns and rotations to climb stairs, go through doors, or go around corners.

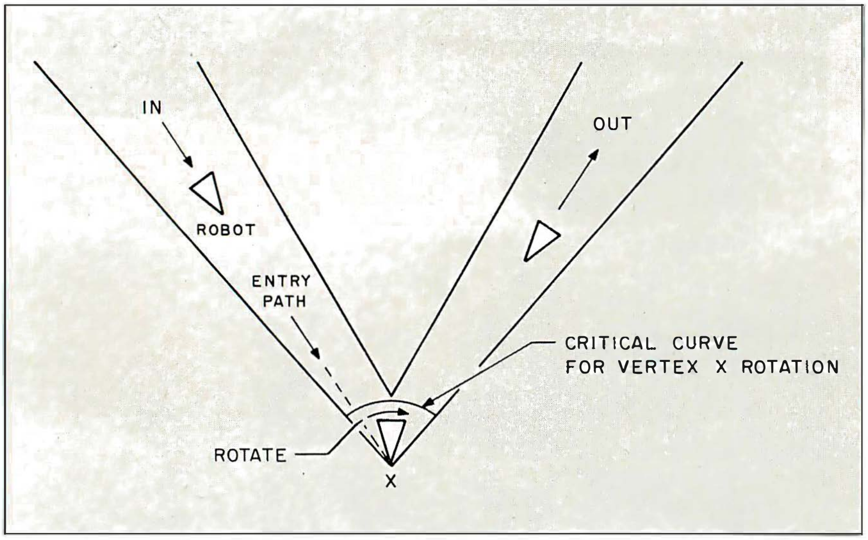


Figure 2: *The piano-mover problem.*

The complexity comes from the fact that, in addition to finding a continuous motion that will take a robot from a given initial position to a final position, the robot is subject to geometric constraints during the motion. The constraints do not permit any part of the irregular robot body to come into contact with obstacle edges or walls.

You can simplify the task by imposing restrictions on the range of allowed robot motions, such as insisting that the robot move in a fixed orientation or that the change of orientation can occur not more than once during a path traversal, but in general the problem is approached as follows.

Each corner of the robot chassis outline is labeled and treated as an axis around which the robot can rotate. The map of the navigation area is divided into regions of open space formed by the intersections of the lines connecting the objects, room walls, and corners. Each region is separated from the other in terms of "critical curves" that are created by the set of points generated when each vertex of the robot outline is placed at an intersection point of two regions, and the robot is rotated around that axis until an intersection occurs with region boundaries.

The set of intersecting curves formed for all the robot vertices composes a finite connectivity graph that contains all possible boundary-crossing rotations of the robot. Algorithms are then applied to this connectivity graph to select a "path" consisting of axis rotations that permit the robot to cross from one region to another. In figure 2, the robot is represented by a triangle and the corridor to be navigated is bent at an angle. To traverse the boundary, the robot must turn right at the first boundary area and move backward down the corridor to fit through.

With the current state of robot sophistication, other factors can overshadow such tight maneuvers in real-life situations. These factors lead us

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to the next level of navigational complexity, the exploration of Columbus.

COLUMBUS

In the navigation of Magellan, the world map existed. Travel involved finding the best path to a goal. Columbus faced a different problem. He knew roughly where he wanted to go, but he had little or no information as to what he would encounter along the way.

Since others felt he might sail off the edge of the world, it was important that he create a detailed record of his journey as he went. The voyage was filled with both perils and great discoveries to record. For an autonomous robot, such situations occur with obstacle avoidance and world mapping through sensors.

Robotic sensors come in many types and include monoscopic and stereoscopic vision systems, fixed and mobile sonar range finders, laser range finders, touch sensors, stress and torque sensors, and collision detectors. For navigation, the most often sought sensor data is used for edge detection.

Vision systems usually encode pictures as matrices of gray-scale pixels that are connected through gradient-seeking algorithms that consider reflectivity, texture, and shading to produce skeletal representations of the scene objects. The skeletal edges are then used to direct turn angles or grasping orientations of end effectors. Using multiple cameras simultaneously permits the estimation of distances through optical parallax.

Lasar range finders allow precise location of edges and can be used in conjuction with other sensors such as those for vision. Touch sensors permit obstacle avoidance through edge following and work well if the objects are not highly irregular. Sonar sensors are widely used in robotics navigation. For a discussion of the nature and limitations of this kind of sensor, see the text box "Sonar Sensors" on page 230.

When the approximate locations of obstacles have been determined, the navigation algorithms use the sensor-generated map to determine admissible paths much like the Magellan example. The situation is more complicated, though, because of the uncertainty that is introduced by sensor errors, fuzzy object shapes, and imprecise destination areas. Depending upon what the robot finds on the way, it may not be possible to reach a goal, and numerous unplanned changes in course may be required. It is also no longer possible to guarantee that the robot is taking the most efficient path to a goal any more than Columbus could guarantee that he had selected the best route to an unexplored continent.

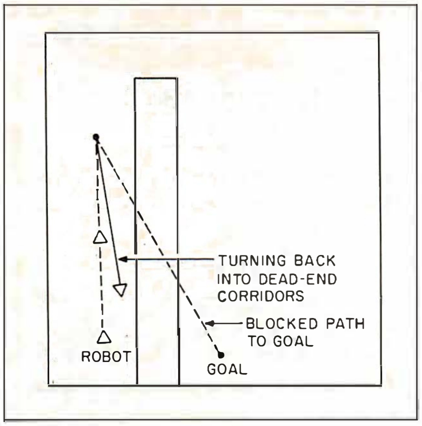


Figure 3: *A simple maze that demonstrates the need for memory in Columbus-level navigation.*

When the environment is only partially known, new issues must be considered that would not occur with a complete world map. Just as Columbus could sail into closed lagoons, a robot can encounter dead-end corridors and mazes when exploring. A maze might be generated by rows of boxes, outdoor canyons, or tangled equipment and can result in a teleoperated robot getting choked by its own power cord. In contrast to Columbus, it is not always easy for a robot to determine that it is in a dead-end situation.

Figure 3 shows a maze problem. Suppose the robot were given a control algorithm like the following:

> When in a new area, first turn toward the location of the goal you wish to reach. Take a sonar reading to see if the path is clear. If the path is clear, then move. If it is not, take the first open path on either side of the line you would have taken if the path had been clear. Go one-half the distance to the goal. When you arrive at that location, turn back toward the goal and repeat the process.

At first glance, such a procedure appears very sensible. The first clear path closest to an ideal straight line is always the one taken. The half-distance criterion assures that if the robot is far from the goal it will move rapidly to it, but it will take smaller, more careful moves the closer it gets.

What, then, is wrong? The problem is that we have not given the robot an ability we take for granted. The robot has no memory. Look again at figure 3. The robot's goal is directly on the other side of a wall. If the robot follows our initial algorithm, it will scan the corridor it is in and select the first open move halfway to the goal after about a 90-degree left turn. The robot will begin to move up the corridor, away from the goal. After a short distance, the robot will be far enough from the goal so that it can travel half the distance by making a turn back toward the goal.

What happens? The robot again moves into the dead-end corridor. Thus, without external memory, our explorer bounces around and never reaches the goal. With a memory, previously explored blocked areas can be set off limits for a goal traversal so the robot is gradually squeezed out of dead-end situations.

Of course, there are many ways we could deal with this problem. The real difficulty is assuring that a general-purpose navigation algorithm considers all the possible traps that can be generated by deficiencies in the robot. Subtle complexities can hide in seemingly simple situations, such as a need to consider multistep memory to avoid recursive loops, a need to explicitly consider trading off distance traveled versus angle turned, and

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SONAR SENSORS

Sonar sensors have proved particularly useful in navigation research, largely because they are relatively inexpensive and able to grossly cover large areas more rapidly than detailed processing with visual systems. Nonetheless, their use in autonomous navigation does pose some problems. Figure A illustrates some of the properties that make "sonars" challenging for use in navigation.

Most low-cost sonar devices function by sending a multifrequency or "chirped" sound pulse from a transducer outward in a cone-shaped wavefront. The difference between the time of emission and return is then used to determine estimated distance calculated on the basis of how far the wave could travel in one-half the period.

Real-world factors intervene when a robot uses that information to construct spatial distance maps from different scanning positions. First, although not of great concern indoors, sonar is sensitive to temperature changes. Specifically, the speed of sound in air is proportional to the square root of the absolute temperature in degrees Rankine (degrees Fahrenheit plus 460). If a sonar range detector is calibrated at a standard temperature *S* and the actual room temperature is *A*, then the actual distance traveled by the sound in the air is the square root of (460 + *A*) / (460 + *S*) times the estimated distance. Thus, if a sonar were calibrated at 80° F and the actual room temperature was 60° F, a measured range of 35 feet would be overestimated by 7.8 inches (see table A). If that 7.8 inches overlapped with the position of a solid object, the difference could provide a shocking experience for a moving robot.

Another property of sound waves is that they exhibit specular reflection and interact with the texture of materials. This interaction was illustrated one day in our laboratory when we were going to demonstrate a small mobile robot for some visitors and decided to give the obstacles colorful coats of shiny new paint. The high gloss was attractive to the human eye but also extremely reflective to sonar, so that if the obstacles were not hit almost head-on by a sonar beam they vanished from the sonar navigation maps. The result was that the robot often rammed into the objects instead of going around them. After trying cardboard, metal, and other coverings, we found that the highest specular reflection was provided by simple plastic bubble wrap. Visitors now see

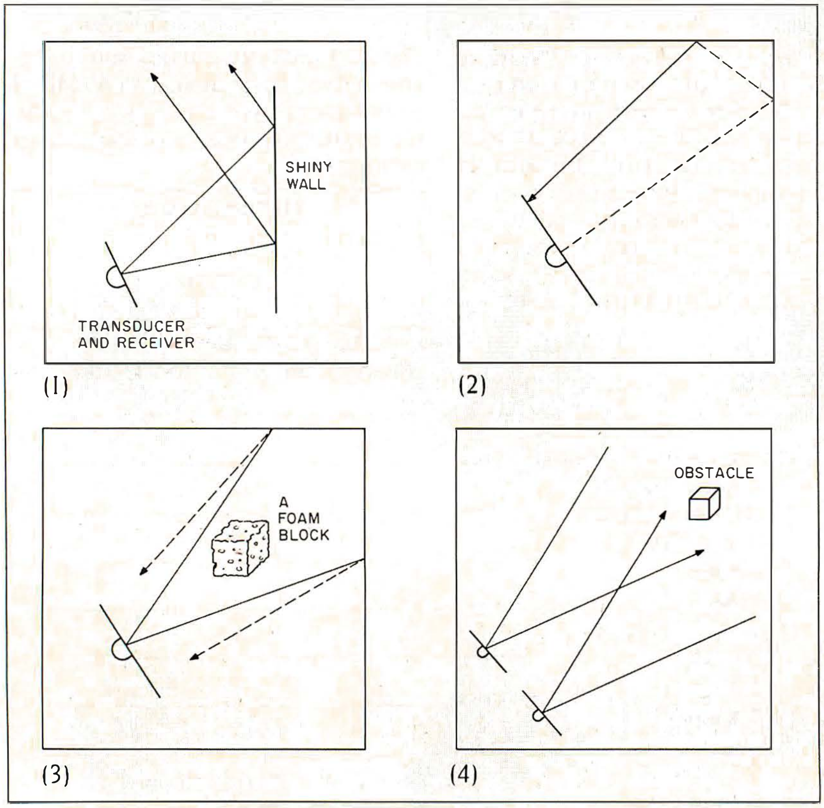


Figure A: *Sonar problems. (1) Specular reflection, (2) false distance readings caused by reflection, (3) absorbancy, and (4) beam focusing.*

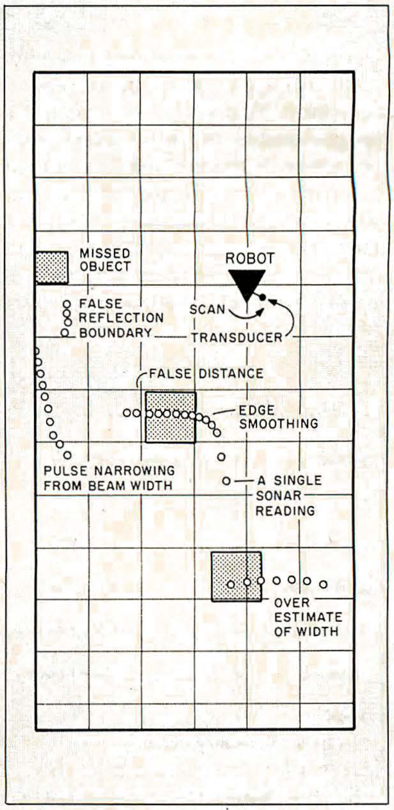


Figure B: *A sonar map of a room. Each grid is two feet square.*

NAVIGATION

Table A: *The equations of sonar in air.*

SPEED OF SOUND IN AIR $S = \sqrt{K_g HRT}$

Where

- S = speed of sound
- K_g = gravitational constant
- H = ratio of specific heats of air at constant pressure to constant volume
- R = gas law constant for air
- T = absolute temperature

ACTUAL DISTANCE $D_s = \sqrt{A_t / S_t}$

Where

- D_s = sonar-measured distance using the above formula
- A_t = actual outside temperature
- S_t = standard temperature

SONAR-CALCULATED DISTANCE $\frac{1}{2} tS$

Where

- t = time between sending and receiving sonar pulse
- S = speed of sound in air

colorful boxes through a fat layer of bubble packing. Since robot designers can't bubble-pack the world, it is obvious that other sensor types must be used in conjunction with sonar for navigation.

The characteristics of reflected sound also depend on signal energy and frequency. Frequencies that are useful in medical imaging, such as ultrasound, are not really practical for robotics because they take advantage of the density of the propagation medium, which is usually a fluid or tissue. Most sonar systems for air rely on a carefully selected subset of frequencies designed to minimize absorption by typical materials. Under some circumstances the frequency will be inappropriate even for head-on readings. An actual example occurred in some initial experiments using robot manipulators that attempted to grasp polyurethane foam blocks, which have extremely high sonar absorbency. For all intents and purposes, these blocks were invisible to sonar.

Other sonar problems occur because of the beam shape. The output of a sonar transducer is actually a cone, like the beam of a flashlight. Without a focusing horn, a typical sonar cone is about 35 degrees wide. Therefore, sonar maps have to take into account that the leading edge of the cone will contact a barrier well before the center axis of the transducer. If the false angular reading is not corrected, the map of an area a robot uses to navigate is distorted. Figure B shows a sonar map made by a robot in the CESAR laboratory that illustrates some of these effects. Specular reflection caused the map to show artificially smoothed edges to boxes, vanishing walls, and falsely closed movement corridors. Beam spread made obstacles that are farther away from the robot appear larger than they really were. Failure to correct for the width of the beam and plotting the distance returns as though they were at the center axis of the sonar resulted in a false inward wall curvature.

Many of these characteristics can be compensated for based on known properties of the sonar beam, but not all. The reason is that, in an unknown room, there is no way to assure that a sonar return is the result of a specular reflection effect instead of an actual return from a new object. Without further verification from different robot positions or alternate sensors such as vision, extraneous information must remain in the sonar map. The correction, or "unfolding," of sensor data thus becomes of major concern the more rapidly navigation decisions must be made.

checking sonar maps to handle changing reflections.

In addition to changing reflections, errors in robot position occur due to the cumulative buildup of mechanical and electronic innaccuracies in the robot propulsion system. Columbus-level navigations must be able to correct a position by keeping track of changing external references. There is also a need to keep track of higher-level global relationships. One problem is identifying and selecting a good reference point. A robot can use such a point to correct cumulative mismatches between what the internal map records as the robot's location and what sensor data indicate are actual object distances and orientations. How to best select and relate such references as well as how to update the internal map are topics still being researched.

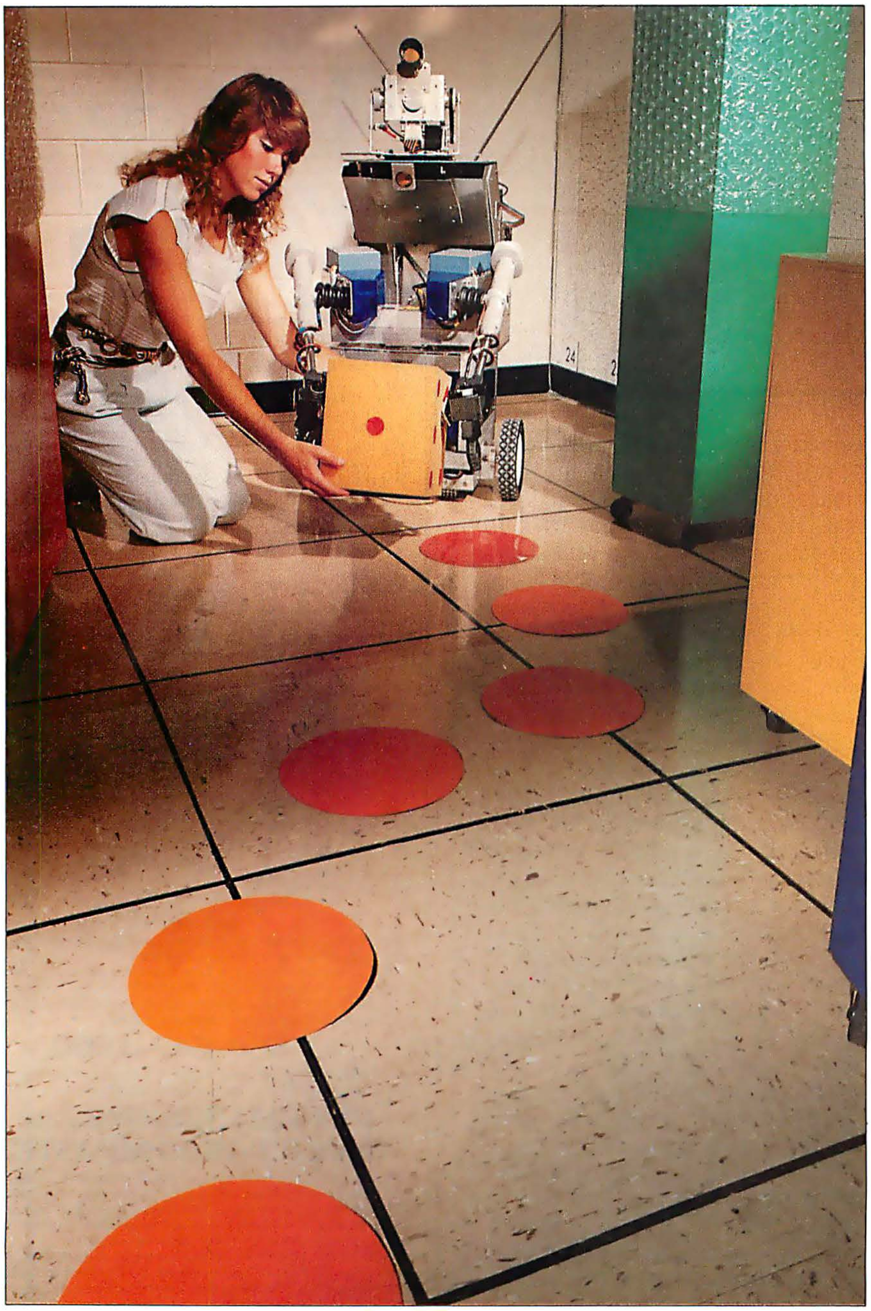


Photo 1: HERMIES *(right) and friend.* Notice *the bubble wrap on the obstacles and the two-feet-square floor grids.*

ULYSSES

Other types of problems occur when navigation in real time is considered. Ulysses had to contend with a multitude of perils on his explorations, but he also faced gods who kept changing his environment by adding threats or removing them.

For an autonomous robot, a similar situation occurs with traversal in an environment where objects move and requires creation of a stack of intermediate goals as changes invalidate global plans. The robot must generate new plans, remove invalid goals from the stack, and break world maps into static and dynamic areas.

Consider a woman walking down a crowded hall who is preoccupied with a schedule and takes only occasional glances to determine if something is in her way. A glance may work as long as the unexpected does not occur. The greater the amount of change in the environment, however, the faster and more frequently she must glance up and the more often she will have to modify a plan to walk straight ahead in order to avoid bumping into people.

A robot in a dynamic environment is in the same situation. Sensor processing speed must be sufficient to recognize changes in the environment before a preplanned action results in a catastrophe. Consider the implications for a Mars Rover that could only process the image of a cliff after rolling over the edge. Although current computer vision systems provide detailed two-dimensional information about the environment, they can be very slow and computation-intensive. The technology is changing, but vision may not be able to effectively handle the full navigation problem. Single-sensor limitations make us want to simultaneously use different kinds of sensors to provide more data. Higher-order logic may then be able to use the increased information

to anticipate serious events before they occur.

Ulysses navigation often creates the need for multiple sources of information to supplement local sensor readings. Sensor speed is important because the total array of sensors must be fast enough to monitor world changes effectively. In addition, multiple sensors increase the importance of future research on databases that combine information into a composite data structure. One such area is robotic learning. An ideal autonomous vehicle would acquire information about its environment on a local basis and at the same time build or modify a global world model that can be used for more complex plans (reference 7).

A Visit with HERMIES

To illustrate how some of these techniques appear in a working system, consider HERMIES (see photo 1). A small mobile robot at Oak Ridge National Laboratory, HERMIES is the prototype of a robot series that contains many of the features needed for autonomous operation in hazardous environments.

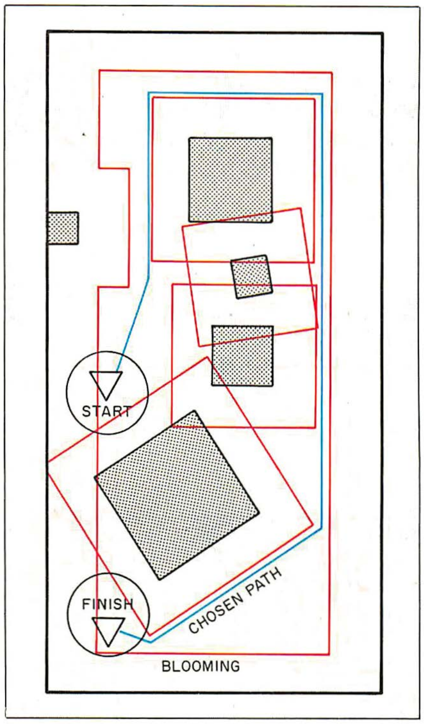


Figure 4: *A Magellan-level navigation by* HERMIES, *showing the original spatial map, the blooming of obstacle diameters by* HERMIES *(red), and the selected path (blue).*

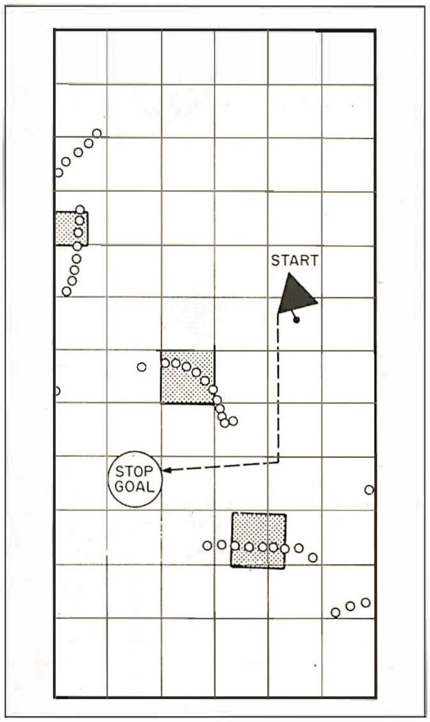


Figure 5: *A Columbus-level navigation by* HERMIES. *Obstacles are drawn into the figure but were not available to the robot. The small circles represent the obstacle locations as they appeared on sonar.*

HERMIES has a self-powered mobile platform with a wheel-driven chassis, dual manipulator arms, on-board distributed processors, and a directionally controlled sensor suite. He is propelled by two independent DC-motor-driven wheels with a common axle alignment. Common motor direction provides forward and reverse motion, while counter driving provides bidirectional pivoting for heading changes. On-board computers consisting of an IBM Personal Computer and a Z8 microprocessor are located in an enclosure mounted above the drive chassis. The PC controls all functions except the arms, which are controlled by the Z8. The dual arm manipulator torso is located above the computers with two five-degrees-of-freedom Hero I arms with added shoulder-pitch motion and a base rotation. At present, the sensory platform at the top of HERMIES has one four-element phased array and a binary vision system positioned by a pan-and-tilt mechanism. The sensor platform is controlled by an open-loop commercial multiaxis stepper controller. HERMIES does not do all planning on board but rather communicates sensor data to a remote LISP machine via a radio frequency link. Thus, all the navigation planning, map construction, and decision making occur in the LISP machine, and decisions are transmitted back to HERMIES as primitive FORTH commands recognized by the robot operating system.

The boxes shown in photo 1 are movable obstacles from which various maze and barrier problems can be constructed. The box mobility also permits experimenters to change the positions of the obstacles as HERMIES navigates. The circular disks on the floor are goal markers so the staff can assess how much cumulative error has been introduced between the internal sonar map of the robot location (displayed in real time on the LISP machine) and the actual location of HERMIES in the laboratory.

Consider first a simple find-path problem. Figure 4 is an example of a spatial map that HERMIES constructed when given a Magellan problem involving four blocks. Notice how the edge of the room and the boxes were "bloomed" (red lines) to allow movement clearances. The blue line shows the computed path to be traveled, which corresponds to the selected vertices of the bloomed boxes. Notice that a shorter path looked possible but the robot did not select it because the clearances of the obstacles were insufficient after the obstacles were bloomed.

Figure 5 shows part of a Columbus problem navigation map generated by sweeping the HERMIES sonar through 180 degrees and recording the returned distances as small circles. The dashed line corresponds to the

(continued)

path selected by HERMIES to avoid the obstacles. The actual shapes of the obstacles are drawn in to illustrate the error introduced by the sonar returns (see "Sonar Sensors" on page 230) and were not available to HERMIES at the time of navigation.

Figure 6 shows part of a Ulysses-level global map that was built in four steps. This information is used to combine the history of multiple journeys for future navigation planning.

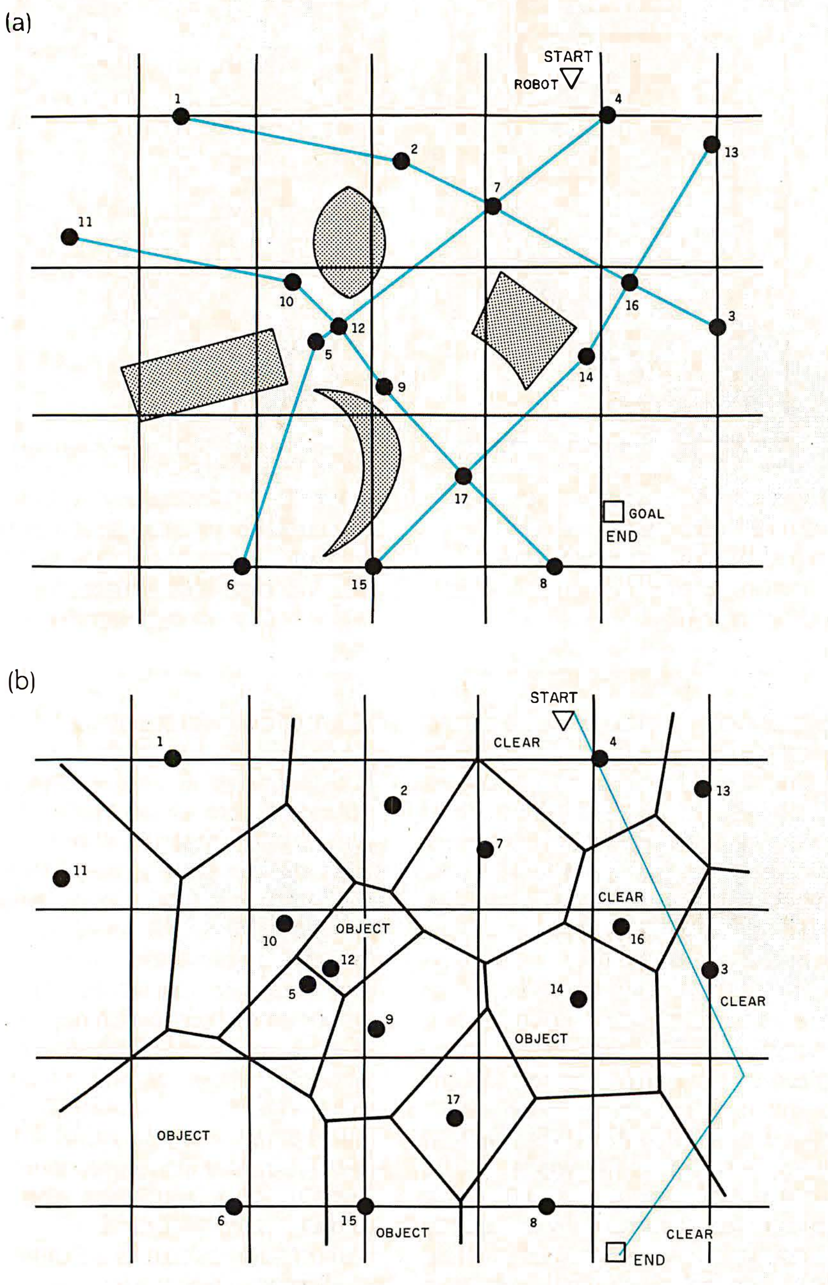


Figure 6: A *Ulysses-level map constructed by* HERMIES. *(a) The obstacle positions before exploration and four paths (blue) from previous traversals around the objects; (b) Voronoi regions are created and labeled from previous path points. The optimal path calculated is shown in blue.*

Figure 6a shows a spatial graph of current obstacle locations and paths from four earlier Columbus-level journeys. Figure 6b is a special type of graphic representation called a Voronoi diagram. Both are used to apply graph theory to the multipath history and calculate a new optimal path from previously learned information. This path would minimize additional sensor use. Learning occurs as new paths are added to the Voronoi diagram and spatial graphs so that, with time, the robot navigation control switches from sensor-driven obstacle avoidance to global graph-based decisions.

FUTURE DIRECTIONS

Advances in robot navigation are occurring very rapidly, so accurate projections about the future are speculative at best. Some trends appear evident, however. Robot navigation planning will move increasingly toward Ulysses-level problems. There will be more concern with the computational and algorithmic requirements of real-time sensor processing and decision making using parallel computer architectures, larger knowledge bases and expert systems, and effective characterization of uncertainty. Sensors will increase in speed and number with improvements being made in integrated functions, such as the use of multiple phased arrays to improve sonar focusing, laser range finders for precise distance and edge detection, touch sensing, and stereoscopic vision.

Future descendants of current mobile robots such as Carnegie-Mellon's Terregator, HERMIES, the University of Tolouse's Hilare, and the Department of Defense's Autonomous Land Vehicle will most likely be faster, smarter, and more aware of their environments than today's prototypes. The mobile robots of the future may well be a new class of explorers that journey to places or planets where people can never go. ■

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The research that is the subject of this article was sponsored by the Office of Basic Energy Sciences of the U.S. Department of Energy under contract No. DE-AC05-840r21400 with Martin Marietta Energy Systems Inc.

FOR FURTHER INFORMATION

For more detail on vision systems, see *Digital Image Processing* by Rafael C. Gonzalez and Paul Wintz (Reading, MA: Addison-Wesley, 1977).

For an interesting study of the Mars Rover, see *Robot Rover Visual Navigation* by Hans P. Moravec (Ann Arbor, MI: UMI Research Press, 1981).

For more detail on robotic arms, see *Teleoperation and Robotics: Evolution and Development*, Robot Technology Series vol. 3A, by Jean Vertut and Philippe Coiffet (London: Kogan Page, 1985).

For information on planning, see *A Structure for Plans and Behavior* by Earl D. Sacerdoti (New York: Elsevier, 1977).

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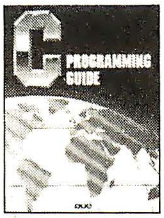
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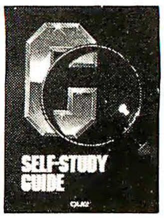


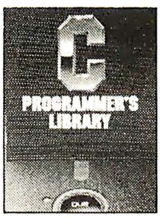
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Inquiry 118

AI IN COMPUTER VISION

BY JOHN L. CUADRADO AND CLARA Y. CUADRADO

Framing doors and windows

COMPUTER VISION INVOLVES a two-stage process: An early processing (sometimes called low-level processing) stage extracts intrinsic information of images, e.g., the gray level at various points on an image plane. This early processing is done very efficiently, albeit unconsciously, in the human visual system. We do not yet understand very well the way it works. In contrast, the late processing (or high-level processing) stage in computer vision uses general assumptions about how the physical world fits together to guide vision. This high-level processing is more easily understood in terms of the human visual system: We constantly utilize domain knowledge to guide our interpretation of images. Here vision becomes inseparable from general cognitive processing. This is the stage where artificial intelligence and vision meet; knowledge representation, inferences, goals, and plans all play an important role in this stage of vision.

In this article we will attempt to illustrate how artificial intelligence techniques can be used to aid computer vision. Because of the complexity and diversity of issues involved in these two fields, we feel it is futile to try to cover current state-of-the-art research. Interested readers should consult references 1, 2, 3, and 4. Instead, we will present a simple computer-vision system that we have constructed for the explicit purpose of demonstrating the role AI may play in a vision system. We will concentrate on the high-level end of the vision hierarchy but we will also point out the interplay between the low-level processes and the knowledge-intensive processes whenever appropriate.

FRAME-BASED KNOWLEDGE REPRESENTATION

Our computer-vision system uses a frame-based knowledge representation to handle all the components in the high-level processing of the vision hierarchy. (Probably the best introduction to the idea of frames and frame-based systems is reference 5. An excellent succinct presentation is also available in reference 6.) The frames structure we use is based on a combination of features from KRL (Knowledge Representation Language), SRL (Schema Representation Language), and FRL (Frame Representation Language). Our frame-based system is implemented in Prolog and includes such features as inheritance and demons.

The basic structure of an abstract frame is shown in figure 1. A frame consists of a name followed by an arbitrary number of slots, each of which can support an arbitrary number of facets. Each facet has an associated value. The data corresponding to these values is not typed data in general, although it is a simple matter to provide mechanisms for the enforcement of strongly typed facets. The value associated with a given facet can be an integer, string, list, or an even more complex object. The most common facet is the value facet.

(continued)

Clara Y. Cuadrado and John L. Cuadrado (Octy Inc., 10920 Oxford Court, Fairfax Station, VA 22039) both earned Ph.D.s from the University of Illinois at Urbana–Champaign. They taught at the University of Maryland and Dartmouth College, respectively, and now run their own company developing AI systems.

This facet refers to the actual value taken by the corresponding slot. Other commonly occuring facets include the default and if__needed facets. A simple example should help to clarify all this terminology.

Consider a simple personal computer consisting of a microprocessor, some memory, a disk drive, a video monitor, and a keyboard. This might be represented as shown in figure 2.

Now, a specific instance of this type of computer could be my computer, as shown in figure 3a. The ako acronym stands for "a kind of" and indicates that my__computer is one of the class of computers having all the characteristics of computer__brandX. In particular, my__computer "inherits" an 8088 processor from the computer__brandX. Similarly, if we want to know what kind of monitor my__computer has, we know that since we did not specify a monitor, my__computer will inherit the black-and-white monitor specified as the default monitor in computer__brandX.

From this simple example we see that we are going to need a number of procedures to retrieve values from frames, to install values in frames, etc. We must also agree on some specific representation for frames using the data-structuring facilities that our implementation language provides.

The implementation we have chosen is to let each slot-facet-value triple be represented as a predicate whose head is the frame name. For example, my__computer in figure 3a would be represented as shown in figure 3b. We have chosen not to implement frames as list structures in Prolog primarily because Prolog does not provide adequate list-surgery operations. This is not an oversight by the designers of Prolog. To perform such list surgery it becomes necessary to do certain manipulations that are against the applicative nature of Prolog. There is a way around it via difference lists, but we will not go into that here.

```
<frame-name>
      <slot-name>
            <facet-name> : value
            .
            .
            .
            <facet-name> : value
      .
      .
      .
      <slot-name>
            <facet-name> : value
            .
            .
            .
            <facet-name> : value
```

Figure 1: *An abstract representation in pseudocode of a frame.*

```
computer__brandX
      cpu
            value : 8088
      memory
            default : 256k
      keyboard
            default : 80__keys
      monitor
            default : black__white
      disk__drive
            default : ss__floppy
```

Figure 2: *A pseudocode representation of a frame defining a kind of microcomputer.*

```
(a)

my__computer
      ako
            value : computer__brandX
      memory
            value : 512k

(b)

my__computer(ako,value,computer__brandX).
my__computer(memory,value,512k).
```

Figure 3: *An instance of a figure 2–type computer in pseudocode (a) and as implemented in Prolog (b).*

Frames in Prolog

In the next few paragraphs, we present a guided tour through the various functions that provide the retrieval and maintenance facilities for this particular representation of frames in Prolog. Each of the sets of functions presented below is organized as a main predicate that provides a general facility, including the ability to handle inheritance and the invocation of suitable demons.

First, we need a function that will retrieve information from the slots in a frame. The predicate frame__get performs such a function. It uses ffget as an auxiliary predicate to handle traversals up the frame hierarchy. The actual code for this function is presented in listing 1. [*Editor's note: The Prolog source code is available for downloading from* BYTE*net Listings at* (617) 861-9764. *The code can be run on* PDPROLOG, *which is also available from* BYTE*net Listings.*]

The next set of predicates provides the facilities to install values in a given slot of a frame. The code for frame__put in listing 1 does this.

Next, we provide a predicate for removing information from a frame, frame__remove (listing 1).

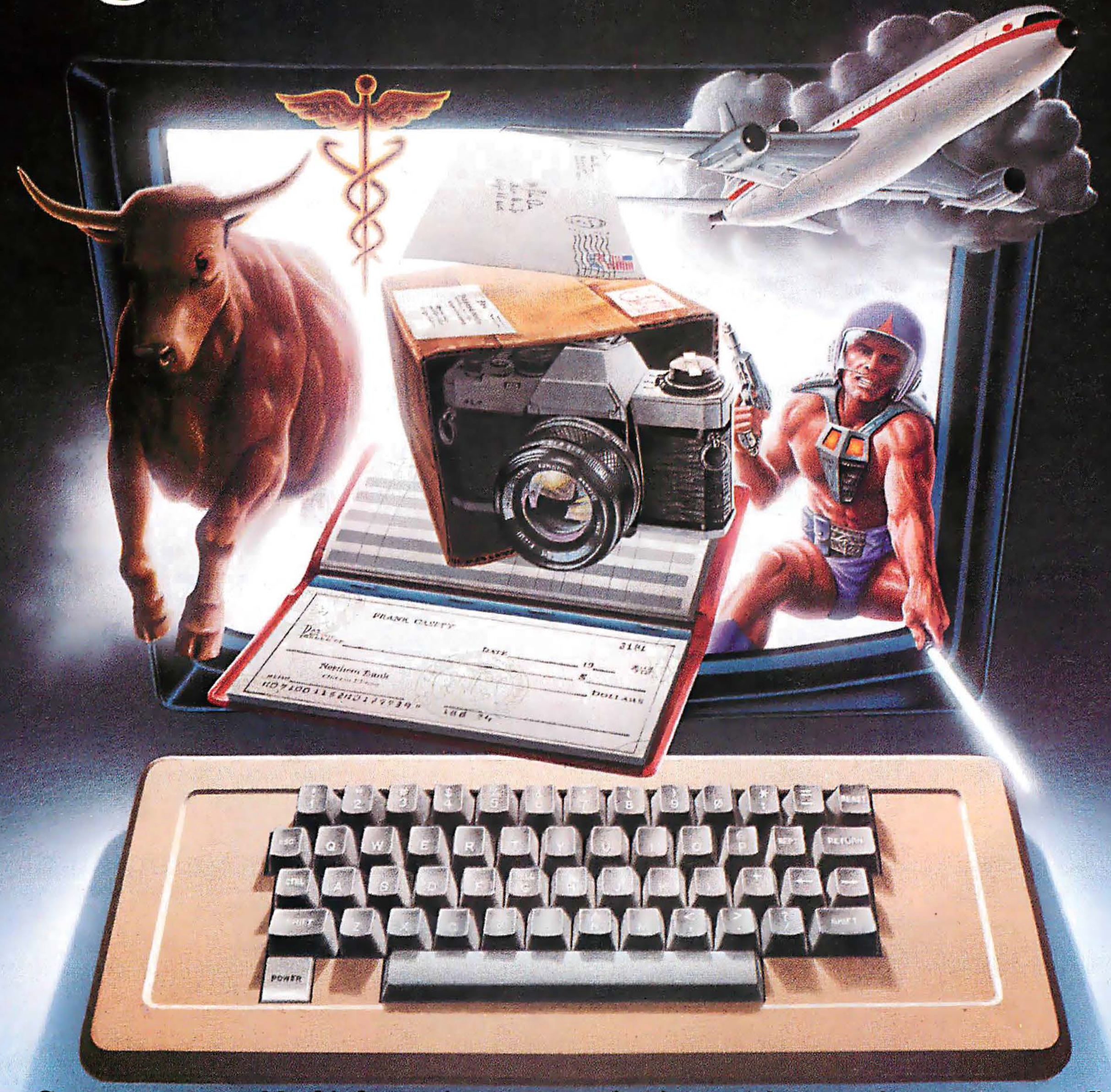
Occasionally, we not only need to install and remove values from some slot in a frame but also need to replace whatever value is in a slot with a new value. In listing 1, frame__replace does this.

Finally, there are times when we need to deal with lists as the values of some slots. Often in these cases we build the lists incrementally. For this reason, we provide the frame__append predicate that appends values to a list in a slot (listing 1).

To further illustrate the use of the frame-retrieval and maintenance

(continued)

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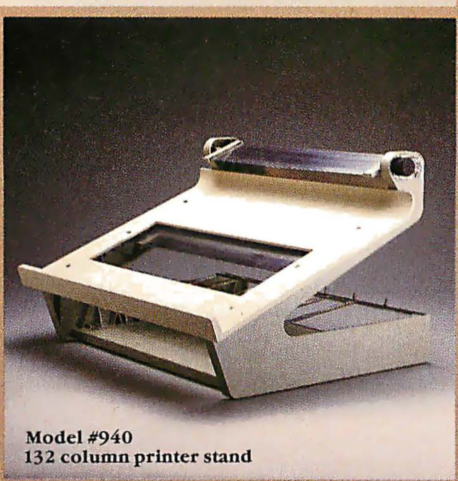
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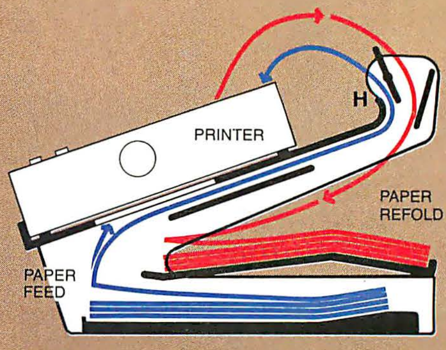
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Listing 1: *The Prolog frame-manipulation routines with an example routine for calculating cylinder attributes.*

```
/* Get the Value of Slot in a given Frame */
frame__get(Frame,Slot,Value) :-
            ffget(Frame,Frame,Slot,Value).

ffget(Parameter__Frame,Frame,Slot,Value) :- /* Check for a value Facet.
*/
            fget(Frame,Slot,value,Value).
ffget(Parameter__Frame,Frame,Slot,Value) :- /* Does it have a default?
*/
            fget(Frame,Slot,default,Value).
ffget(Parameter__Frame,Frame,Slot,Value) :- /* How about a demon?
*/
            fget(Frame,Slot,if__needed,Rule),
            F =.. [Rule,Parameter__Frame,Value],
            F.
ffget(Parameter__Frame,Frame,Slot,Value) :- /* None of the above. */
            fget(Frame,ako,value,Parent),   /* So, move up the hierarchy.
*/
            ffget(Parameter__Frame,Parent,Slot,Value).
fget(Frame,Slot,Facet,Value) :- /* Just grab the given Facet or
fail. */
            F =.. [Frame,Slot,Facet,Value],
            F.

/* Put Value in Slot of a given Frame. If this Slot has an associated
   if__added demon, then grab it and execute it after installing the
   given Value.
*/
frame__put(Frame,Slot,Value) :-
            get__rule(Frame,Slot,if__added,Rule), /* Must we do something
extra? */
            fput(Frame,Slot,value,Value),
            F =.. [Rule,Frame,Value],
            F.
frame__put(Frame,Slot,Value) :-
            fput(Frame,Slot,value,Value).          /* Just a simple fput will
do. */

fput(Frame,Slot,Facet,Value) :-
            F =.. [Frame,Slot,Facet,Value],
            assertz(F).

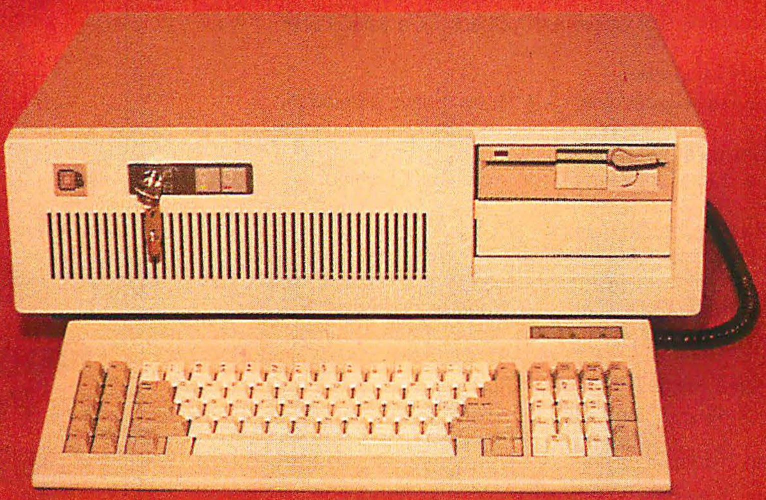
/* Remove Slot from a given Frame. If the Slot has an associated
   if__removed demon, then grab the rule and execute it before
   removing the Slot.
*/
frame__remove(Frame,Slot) :-
            get__rule(Frame,Slot,if__removed,Rule), /* Something extra to
do. */
            F =.. [Rule,Frame],
            F,
            fremove(Frame,Slot).
frame__remove(Frame,Slot) :-
            fremove(Frame,Slot).          /* Just a simple fremove. */

fremove(Frame,Slot) :-
            F =.. [Frame,Slot,value,Value],
            retract(F).
fremove(__,__).          /* If Slot doesn't exist, then no harm done. */

/* Replace whatever is in Slot with Value. If the Slot has an associated
   if__replaced rule, then grab it and execute it after doing the
   replacement.
```

(continued)

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```
*/
frame_replace(Frame,Slot,Value) :-
            get_rule(Frame,Slot,if_replaced,Rule), /* Something extra to
do. */
            freplace(Frame,Slot,Value),
            F =.. [Rule,Frame],
            F.
frame_replace(Frame,Slot,Value) :-
            freplace(Frame,Slot,Value).            /* Just a simple
replace. */

freplace(Frame,Slot,Value) :-
            fremove(Frame,Slot),
            frame_put(Frame,Slot,Value).

/* Append Value to the list in Slot. If Slot has an associated
   if_appended rule, then grab it and execute it after appending
   the Value.
*/
frame_append(Frame,Slot,Value) :-
            get_rule(Frame,Slot,if_appended,Rule),
            fappend(Frame,Slot,Value),
            F =.. [Rule,Frame],
            F.
frame_append(Frame,Slot,Value) :-
            fappend(Frame,Slot,Value).

/* Here we check to see if the slot already exists.

    If it does, then we just append the new Value to the old value
list.
    If the Slot does not exist, then we create it and give it a value
    consisting of the list whose single element is Value.
*/
fappend(Frame,Slot,Value) :-
            fget(Frame,Slot,value,Old),
            (member(Value,Old)
            ;
             fremove(Frame,Slot),
             fput(Frame,Slot,value,[Value4Old])
            ).
fappend(Frame,Slot,Value) :-
            fput(Frame,Slot,value,[Value]).

/* This is a simple utility predicate used to travel up the frame
   hierarchy looking for an appropriate rule to grab.
*/
get_rule(Frame,Slot,Type,Rule) :-
            fget(Frame,Slot,Type,Rule).
get_rule(Frame,Slot,Type,Rule) :-
            fget(Frame,ako,value,Parent),
            get_rule(Parent,Slot,Type,Rule).

/* Example

frame representation:

    cylinder
        ako
                value : thing
        height
                if_added : cylinder_height_add
                if_removed : cylinder_height_remove
        radius
                if_added : cylinder_radius_add
                If_removed : cylinder_radius_remove
```

(continued)

```
        cross_section
              if_needed : cylinder_cross_section
        volume
              if_needed : cylinder_volume

     cylinder1
        ako
              value : cylinder

comments: cylinder1 above is an instance of cylinder. When we use
frame_put(cylinder1,radius,2), say, the system will install the number "2" as the
value of cylinder1's radius and it will further compute cylinder1's cross sectional
area and install it under the cross_section slot. Similar actions take place when we
do a frame_put for cylinder1's height. Below is the Prolog code that implements
all this. NOTE: PDPROLOG only supports integer arithmetic.
*/

cylinder(ako,value,geometric_object).
cylinder(height,if_added,cylinder_height_add).
cylinder(height,if_removed,cylinder_height_remove).
cylinder(radius,if_added,cylinder_radius_add).
cylinder(radius,if_removed,cylinder_radius_remove).
cylinder(cross_section,if_needed,cylinder_cross_section).
cylinder(volume,if_needed,cylinder_volume).

/* If we get the height, then we try to compute the cylinder's
   volume.
*/
cylinder_height_add(Cylinder,_) :-
      cylinder_volume(Cylinder,_).
cylinder_height_add(_,_).        /* If we can't do it,
                                    e.g., the radius is unknown,
                                    then no harm done. */

/* If the height is removed, then the old volume is no
   longer valid.
*/
cylinder_height_remove(Cylinder) :-
      frame_remove(Cylinder,volume).

      /* If we get the radius, then we can compute the cylinder's
   cross sectional area.
*/
cylinder_radius_add(Cylinder,_) :-
      cylinder_cross_section(Cylinder,_).

/* If the radius is removed, then the old cross sectional area
   is no longer valid.
*/
cylinder_radius_remove(Cylinder) :-
      frame_remove(Cylinder,cross_section),
      frame_remove(cylinder,volume).

/* PDPROLOG does not support floating-point arithmetic, so if you are
   using that version, change pi to an integer value.
*/
cylinder_cross_section(Cylinder,Cross_Section) :-
      frame_get(Cylinder,radius,Radius),
      Cross_Section is 3.1416*Radius*Radius,
      freplace(Cylinder,cross_section,Cross_Section).

cylinder_volume(Cylinder,Volume) :-
      frame_get(Cylinder,cross_section,Cross_Section),
      frame_get(Cylinder,height,Height),
      Volume is Height*Cross_Section,
      freplace(Cylinder,volume,Volume).

cylinder1(ako,value,cylinder).
```

predicates, we present an example. It describes a frame for a general cylinder and provides demons for calculating the cross-sectional area and volume. The code in listing 1 from the "Example" remark to the end of the listing accomplishes this.

In the above, we have presented a brief review of the concept of frame-based representation and provided enough frame-building tools so that anyone wishing to embark on the design of a frame-based system can utilize this skeleton to get started. Next, we will describe the workings of a vision system that incorporates these ideas.

A Simple Vision System

Sometime last year an architectural firm (let's call it Palladio Associates) came to us with a request for the design and implementation of a system capable of interpreting house drawings. They needed a system to classify houses according to a fixed number of models. They also wanted the system to make recommendations on possible improvements that could be made to a set of sample houses to make them conform more closely to the models. It was also important that the system be capable of justifying (explaining) any recommendations that it would make.

After talking with representatives from Palladio Associates, we learned that the number of their model houses was very small. We also learned that the sample houses to be presented to the system fell into well-defined, narrow categories with only some fairly straightforward differences between the samples and the models. The folks at Palladio also revealed that they had purchased adequate digitizing equipment to convert the pictures of the houses into what were essentially sharply segmented line drawings.

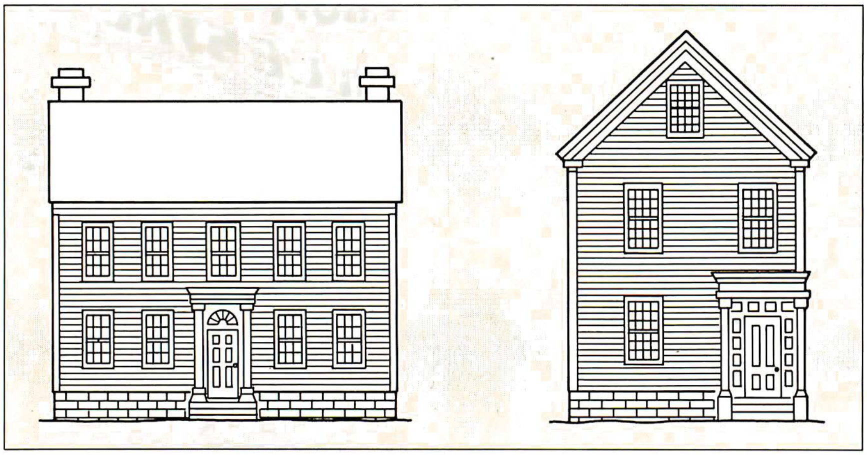


Figure 4: *Two house models used by "Palladio Associates."*



Figure 5: *Sample houses to be analyzed by the architectural program.*

Figure 4 shows line drawings of two of Palladio's house models. Figure 5 shows similar line drawings of two of the sample houses. We were also given a set of what the architects considered acceptable window, door, and siding styles to go with these traditional-style houses. Equally important was a set of window, door, and siding styles that the architects considered in poor taste, yet which would appear in the sample houses. They further made recommendations on which acceptable windows should replace which inadequate ones, etc. Confident that Palladio's requests for the sytem's features were manageable, we decided to undertake the project.

After agreeing to take on the job, we met with the architects from Palladio to come up with an initial set of system requirements. Since the digitizing equipment was already available, this presented no real problem. At this meeting the architects expressed an interest in having the capability to input sample houses to the system by using an icon-driven drawing system that they had just purchased for their computer. This did not present any additional problems. In fact, input from the icon-driven system would be simpler to deal with than input from the digitizer since, for example, the windows and doors would already be labeled according to their categories.

The Housing Project

We will now describe the overall system architecture that we used in the project and explain the flow of information through the system.

Figure 6 is a diagram of the structure of the system. As indicated by box 2 in figure 6, you interact with the system by specifying one or more sample houses that you wish to have

(continued)

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the system analyze. You can have a picture digitized, or you may instead choose to input a line drawing using the icon-driven drawing system.

All system interactions are ultimately controlled by the inference engine (figure 6, box 1). It has a set of top-level routines that schedule when other processes in the system get to execute. Whenever some process in the system finishes executing, it passes control back to these top-level routines in the inference engine. The inference engine also provides a number of generic routines that are available to the rest of the system.

The core of the frame utilities component of the system (figure 6, box 0) has already been described in the previous section. The routines provided by this component are also generally available to the rest of the system and can be considered as providing another, higher-level language on top of Prolog.

After the image of a house has been suitably massaged by the low-level system components in boxes 3 and 4 in the diagram, the information then flows on to box 5. It is here that the system attempts to put together a higher-level description of the image. First, as depicted in figure 7, a set of processes partitions the image into "global house coordinates" and assigns sets of these coordinates to each of the major features of the house, for example, the windows and doors. The main goal here is to partition the house into a set of vertical and horizontal components, each of which contains some house feature that later system phases will find interesting. The general scheme here is basically a simple relaxation technique that first tries to partition the house into three vertical components and three horizontal components. By attempting to isolate significant features in each of the components, the process either increases or decreases the number of components. In the simple houses that the system deals with, the process usually converges very rapidly, and it takes only a couple of passes to settle down to a final partition. What we mean by "global house coordinates" is simply a left-to-right and bottom-to-top assignment of natural numbers to each of the partitions in the image, as illustrated in figure 7. During this phase the system also attempts to classify the windows and doors in the house and match them against the model windows and doors provided by the system. The frame representation of one of the system's models is shown in listing 2.

The processes in box 6 of figure 6 now take over and attempt to construct a frame representation of the entire house. This representation incorporates all the information from the intermediate processes in box 5, but it also discards the pixel-level information from boxes 3 and 4. The

(continued)

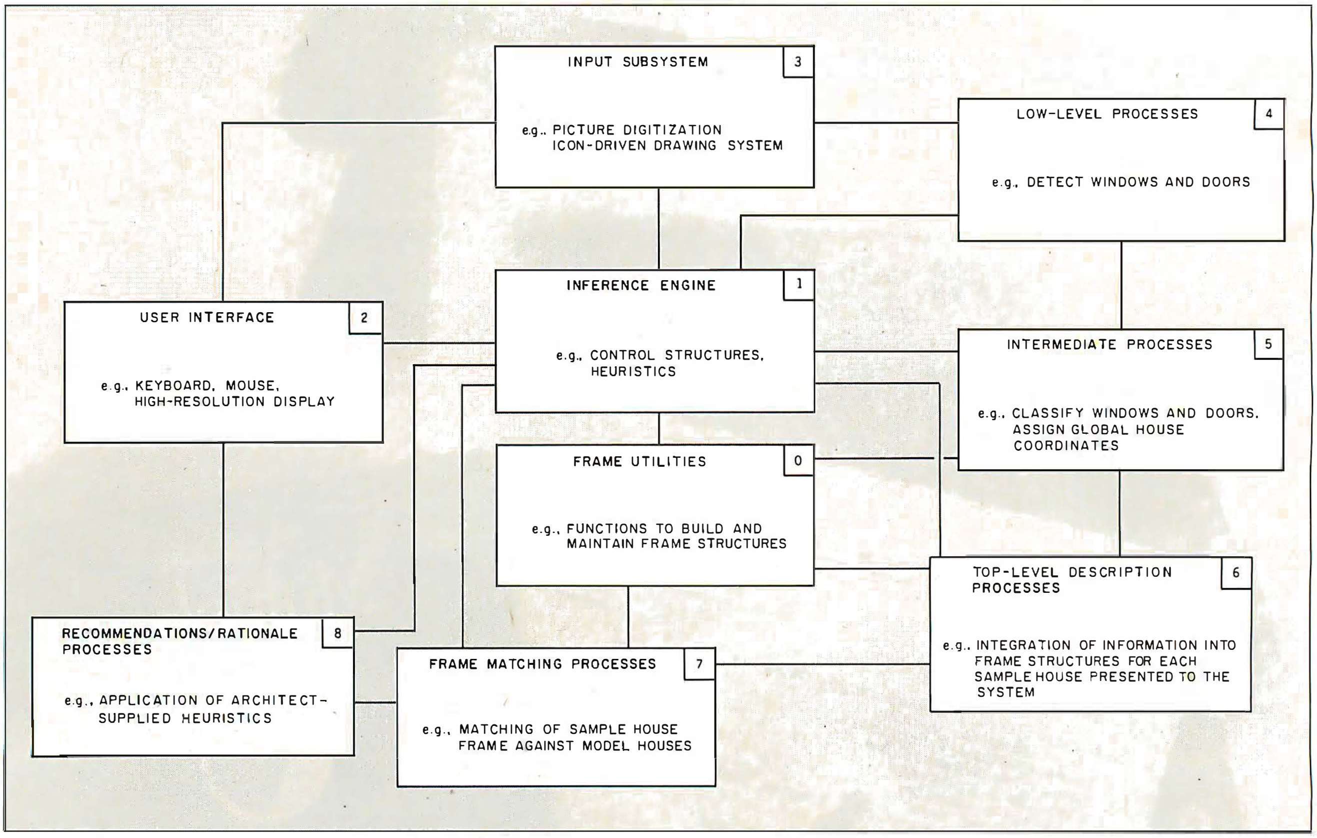


Figure 6: *Diagram of the structure of the architectural system.*

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frame representation generated by the system for a typical sample house is shown in listing 3.

From here on, the system works with the frame representations exclusively. The processes in box 7 attempt to match the frame representation of the sample house against the model frames provided by the system. The matching process is very forgiving and utilizes a set of heuristics to include or ignore features that are considered relevant for a global match.

After the system has produced what it considers to be a suitable matching between the sample and one of the models, it passes control back to the top-level inferencing component. The system then invokes the final set of processes in box 8, which analyze the sample frame and the model and use a set of the heuristics supplied by the architects to make recommendations on how to modify the sample house to make it conform to the model more closely. The recommendations are coupled with various explanations based on the types of windows, doors, etc., and why the architects feel it would be more appealing to remodel according to some given plan.

Epilog

The simple system presented in this article illustrates how techniques in artificial intelligence, such as frame-based knowledge representation, can be used in a vision system to provide a very high-level representation of the information contained in simple, well-specified images. The system works because the set of alternatives it has to consider is very small. The system only "knows" a very limited set of window, door, and siding types, some symmetries, and a few relatively simple heuristics relating to the interplay among these well-defined categories.

While we spare no effort in encouraging our readers to try their hands at applying AI techniques to their computer-vision problems, we hasten to add that the gap between our system and something like the ACRONYM system at Stanford (described in reference 7) is enormous. General-purpose systems like ACRONYM have to deal with issues that are not even addressed in the current system. It is important that our readers refrain from extrapolating the capabilities shown in the simple system described in this article into realms for which it was never intended.

Having said all that, we hope that our little system demonstrates that, given a narrow domain with relatively little noise, it is fairly straightforward to construct systems that have reason-

(continued)

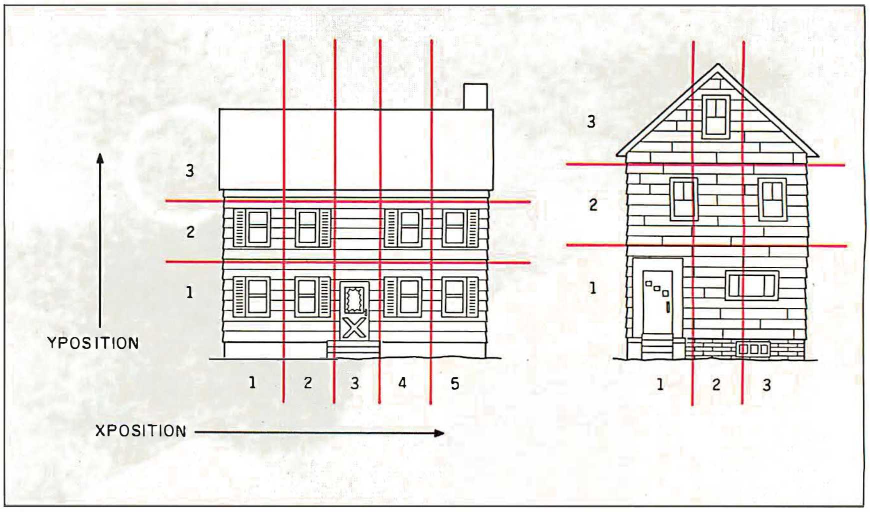
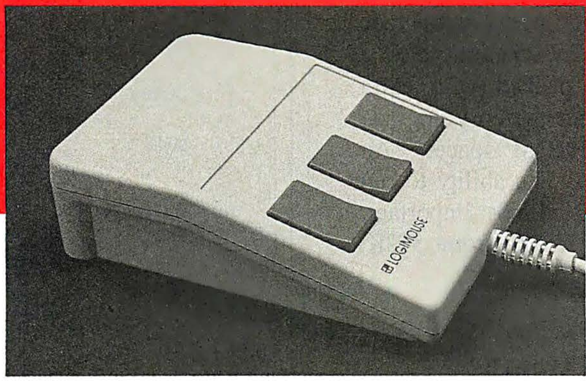


Figure 7: *Global house coordinates showing the partitioning of a sample house by the program.*

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VISION AI

Listing 2: *The frame representation of one of the architectural system's house models.*

```
window__type1
        ako
                value : window
        panes
                value : 12
        style
                value : sash
window__type2
        ako
                value : window
        panes
                value : 24
        style
                value : sash
window__type3
        ako
                value : window
        panes
                value : 3
        style
                value : picture
window__type4
        ako
                value : window
        panes
                value : 3
        style
                value : sash
window__type5
        ako
                value : window
        panes
                value : 2
        style
                value : sash
window
        ako
                value : thing
        area
                if__needed : window__area
window__area(Window,Area) :-
        fget(Window,height,Height),
        fget(Window,width,Width),
        Area is Height * Width,
        freplace(Window,area,Area).
door__type1
        ako
                value : door
        panels
                value : 4
        symmetry
                value : yes
        doorway
                value : [columns,fan__light]
door__type2
        ako
                value : door
```

(continued)

 Inquiry 108

```
panels
        value : 6
symmetry
        value : yes
doorway
        value : [columns, portico, side_windows]

door_type3
    ako
        value : door
    panels
        value : 0
    symmetry
        value : no
    doorway
        value : []

door
    ako
        value : thing
    area
        if_needed : door_area

door_area(Door,Area) :-
    fget(Door,height,Height),
    fget(Door,width,Width),
    Area is Height * Width,
    freplace(Door,area,Area).

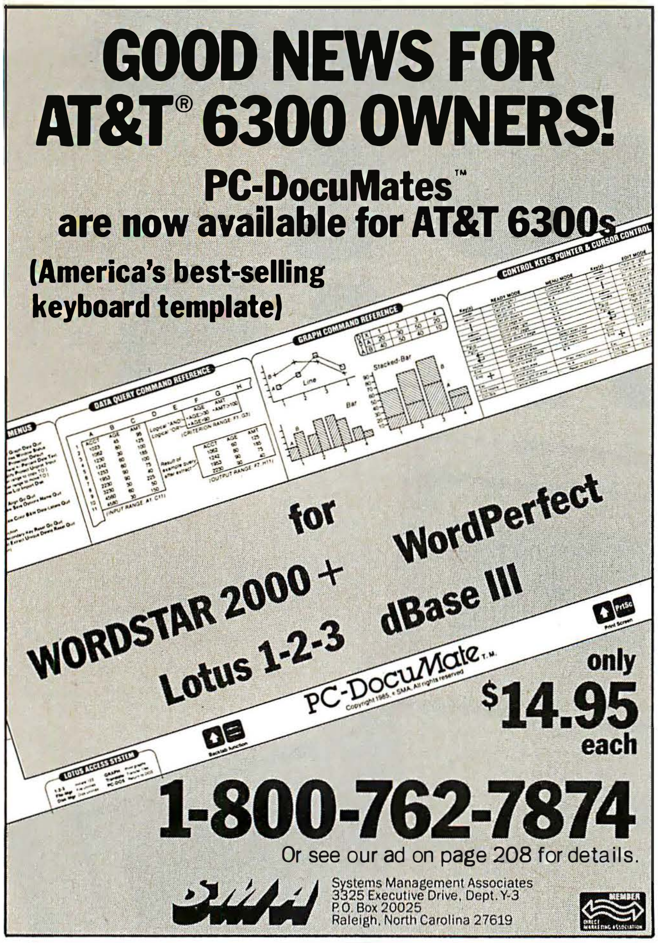
siding_type1
    ako
        value : siding
    material
        value : clapboard
    width
        value : narrow
    cornerboard
        value : yes

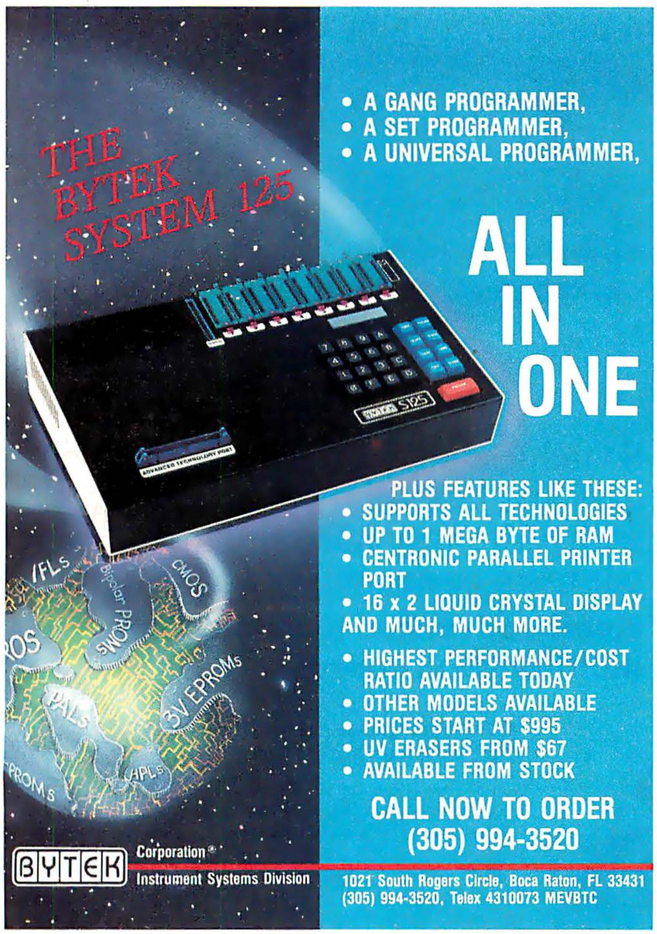
siding_type2
    ako
        value : siding
    material
        value : aluminum
    width
        value : wide
    cornerboard
        value : no

siding
    ako
        value : thing

house_type1
    ako
        value : house
    stories
        value : 3
    siding
        value : siding_type1
    roof
        value : gable
    window1
        optional : yes
        xposition : 2
        yposition : 3
        type : window_type2
```

(continued)






```
        window2
                xposition : 1
                yposition : 2
                type : window__type2
        window3
                xposition : 3
                yposition : 2
                type : window__type2
proto__house
        ako
                value : house__type1
        window4
                xposition : 1
                yposition : 1
                type : window__type2
        door
                xposition : 3
                yposition : 1
                type : door__type1
proto__house__mirror__image
        ako
                value : house__type1
        window4
                xposition : 3
                yposition : 1
                type : window__type2
        door
                xposition : 1
                yposition : 1
                type : door__type1
```

Listing 3: *The frame representation generated by the architectural system of a sample house.*

```
house17
        ako
                value : house
        stories
                value : 3
        siding
                value : siding__type2
        roof
                value : gable
        window1
                value : w7
        window2
                value : w12
        window3
                value : w17
        window4
                value : w23
        door
                value : door37
w7
        ako
                value : window__type4
        ipo                                     /* is__part__of */
                value : house17
        xposition
                value : 2
```

(continued)

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```
        yposition
                value : 3
w12
        ako
                value : window__type4
        ipo
                value : house17
        xposition
                value : 1
        yposition
                value : 2
w17
        ako
                value : window__type4
        ipo
                value : house17
        xposition
                value : 3
        yposition
                value : 2
w23
        ako
                value : window__type3
        ipo
                value : house17
        xposition
                value : 3
        yposition
                value : 1
door37
        ako
                value : door__type3
        ipo
                value : house17
        xposition
                value : 1
        yposition
                value : 1
```

able performance using a modest set of generally available and easily understood tools. ■

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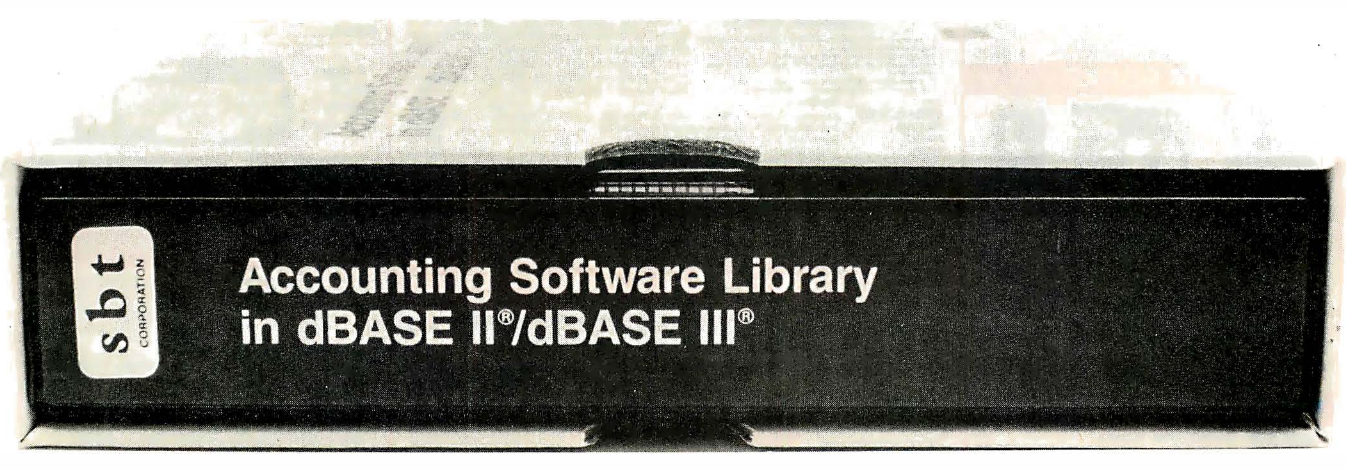
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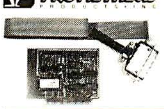
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The JE877 serves as a diagnostic tool, an assurance/maintenance tool and a dual disk drive controller. The JE877 will verify and check the operating hardware of your system each time you turn on your Apple II, II+ or *IIe**. Test your RAM, ROM, CPU, and disk drives. Diagnostic routines may be cancelled at the touch of a key. Complete with instructions

JE877 (DRV-1/Applesurance II). $69.95

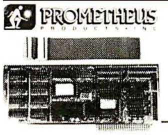
PROMETHEUS PRODUCTS INC — Parallel Printer Card For Apple II, II+ and *IIe**



The JE880 Printer Interface board is an intelligent interface to most of today's popular dot-matrix graphics printers. The JE880 is fully compatible with Apple CP/M, Apple Pascal (or FORTRAN), and most other operating systems and software packages available for Apple II, II+ and *IIe**. The JE880 is shipped configured for the Centronics standard and can be re-configured for other standards if necessary. Advanced text printing features include: video screen echo ON or OFF, auto/disable linefeed after carriage return, set/clear the 8th bit of the output data, set left margin and more! Complete with instructions.

JE880 (PRT-1). $59.95

PROMETHEUS PRODUCTS INC — Parallel/Serial Buffer Card For Apple II, II+ and *IIe**

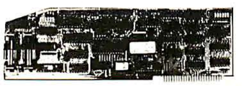


The JE883 provides the user with up to 64K of additional or buffered memory (18 pages of information). Using the parallel jumper cable supplied, the JE883 will attach to the JE880 (above). Parallel Card needed for operation. The JE883 includes a standard parallel input with both parallel and serial (RS232) buffered outputs. With these features you may access and buffer information to two types of printers (one serial, one parallel) simultaneously. Complete with instructions.

JE883 (P/S Buffer). $79.95

*APPLE, APPLE II, II+ and IIe are registered trademarks of Apple Computers

PROMETHEUS PRODUCTS INC — NEW! — VERSACARD for the Apple II, II+ and *IIe**



VERSACARD provides the Apple user with four most popular functions on one physical card. Through hardware address decode, VERSACARD looks to the Apple as if three different cards are installed: Serial, Parallel, Real Time Clock/BSR Control Interface. VERSACARD's hardware maintains complete compatibility with CP/M, Apple Pascal, and Apple ProDos, with no need for special disks. In addition, all standard Apple software using the PR# and IN# commands work normally.

• 4 Functions on 1 card, Serial, Parallel, Real Time Clock/Calendar, BSR
• True simultaneous operation — Your Apple thinks separate cards are installed
• Fully compatible with Apple Pascal, CP/M, Apple ProDos and other Apple software
• No special disks or modifications to your Apple
• Now optional Graphitti Graphics Screen Dump ROM

Part No.	Description	Price
VERSACARD	4 functions on one card: SERIAL, PARALLEL, REAL TIME CLOCK/CALENDAR, BSR. . .	$169.95
PM-ROM (______)*	Graphitti Upgrade ROM (Allows high resolution graphics).	$39.95
PM-SC	Serial Cable for VERSACARD: S26-5'-DB25P (Male).	$24.95
PM-PC	Parallel Cable for VERSACARD: S20-5'-Centronics (Male).	$24.95

*Please specify printer — Available for OKI 80/90 Series, Epson/Star, NEC/C-Itoh, Apple Dot Matrix, IDS and Compatibles of printers listed

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IBM PC/XT Compatible Keyboard



IBM-5151 (Equivalent to Keytronics™ 5151). **$129.95**

Additional Add-Ons Available!

IBM-Case	Computer Case.	$ 59.95
IBM-KB	Keyboard.	$ 79.95
IBM-FCC	Disk Controller.	$ 79.95
IBM-MCC	Monochrome Card.	$ 99.95
IBM-MON	12" Monitor.	$109.95
IBM-ICB	Color Card.	$149.95
IBM-E384K	384K RAM Card.	$199.95
IBM-MB	Motherboard.	$349.95
IBM-10MBK	10MB HH Hard Kit.	$599.95
IBM-20MBK	20MB HH Hard Kit.	$799.95

IBM PCXT Equivalent 130 Watt Power Supply



UPGRADE YOUR PC!

• Input: 110V @ 60Hz • Output: +5VDC @ 15A, −5VDC @ 0.5A, +12VDC @ 4.2A, −12VDC @ 0.5A • Plug compatible connectors • Fits into IBM PC • Weight: 6 lbs.

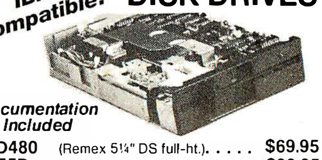
IBM-PS. $99.95

Prometheus Modems

The ProModem 1200B/BS is a 1200/300 baud modem card which plugs into IBM PC and XT. Provides a third serial Comport. Two versions available: 1200B (without software) and 1200BS (with software). The PM1200BS is supplied with powerful MITE communications software from Mycroft Labs. Software available: PC DOS or MS DOS.

PM1200B (without Software). **$239.95**
PM1200BS (with MITE Software). **$274.95**

IBM Compatible! DISK DRIVES



Documentation Included

RFD480	(Remex 5¼" DS full-ht.).	$69.95
FD55B	(Teac 5¼" DS half-ht.).	$99.95
SA455	(Shugart 5¼" DS half-ht.). . . .	$99.95
TM100-2	(Tandon 5¼" DS full-ht.).	$99.95

JMR 5¼" DISK DRIVE ENCLOSURES

Complete with power supply, switch, power cord, fuseholder and connectors

DDE-1FH (Houses 1 full-ht. 5¼" floppy drive) . . **$ 69.95**
DDE-2HH (Houses 2 half-ht. 5¼" floppy drives — vertical). . . . . **$ 79.95**
HDDE-1FH (Houses 1 hard drive). **$199.95**

General Application Keyboards

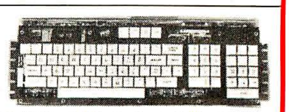
Mitsumi 54-Key Unencoded Keyboard



• SPST keyswitches • 20 pin ribbon cable connection • Low profile keys • Features: cursor controls, control, caps (lock), function, enter and shift keys • Color (keycaps): grey • Weight: 1 lb. • Pinout incl. • Size: 13⅛"L x 4¼"W x ¾"H

KB54. . . . . $9.95

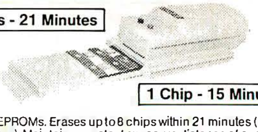
74-Key ASCII Cherry Keyboard



• 7-bit parallel ASCII • Full Upper Case, Full Lower Case except l, m, n, o and p. • Cursor keypad • SPST mechanical keyswitches • 26-pin header connector • Color: white • Size: 18"L x 6¼"W x 1¼"H • Spec included

KB8201. . . . . . *(1500 available)* $14.95

UV-EPROM ERASER



8 Chips - 21 Minutes
1 Chip - 15 Minutes

Erases all EPROMs. Erases up to 8 chips within 21 minutes (1 chip in 15 minutes). Maintains constant exposure distance of one inch. Special conductive foam liner eliminates static build-up. Built-in safety lock to prevent UV exposure. Compact — only 9.00"L x 3.70"W x 2.60"H. Complete with holding tray for 8 chips.

DE-4 UV-EPROM Eraser. **$74.95**
UVS-11EL Replacement Bulb. **$17.95**

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7400

Part No.	Pins	Price
SN7400N	14	.19
SN7401N	14	.19
SN7402N	14	.19
SN7403N	14	.19
SN7404N	14	.25
SN7405N	14	.29
SN7406N	14	.29
SN7407N	14	.29
SN7408N	14	.25
SN7409N	14	.29
SN7410N	14	.19
SN7411N	14	.29
SN7412N	14	.35
SN7413N	14	.35
SN7414N	14	.45
SN7416N	14	.35
SN7417N	14	.35
SN7420N	14	.19
SN7421N	14	.35
SN7422N	14	.49
SN7423N	16	.49
SN7425N	14	.39
SN7426N	14	.29
SN7427N	14	.29
SN7428N	14	.45
SN7430N	14	.19
SN7432N	14	.29
SN7433N	14	.45
SN7437N	14	.29
SN7438N	14	.29
SN7439N	14	.69
SN7440N	14	.15
SN7441N	16	.89
SN7442N	16	.45
SN7443N	16	.79
SN7444N	16	.79
SN7445N	16	.69
SN7446N	16	.79
SN7447N	16	.79
SN7448N	16	.79
SN7454N	14	.19
SN7459N	14	.59
SN7460N	14	.25
SN7470N	14	.39
SN7472N	14	.39
SN7473N	14	.35
SN7474N	14	.35
SN7475N	16	.39
SN7476N	16	.35
SN7479N	14	4.95
SN7480N	14	.59
SN7482N	14	.95
SN7483N	16	.49
SN7485N	16	.55
SN7486N	14	.35
SN7489N	16	1.95
SN7490N	14	.39
SN7491N	14	.69
SN7492N	14	.49
SN7493N	14	.35
SN7494N	14	.89
SN7495N	14	.49
SN7496N	16	.65
SN7497N	16	2.69
SN74100N	24	1.75
SN74105N	14	.99
SN74107N	14	.19
SN74109N	16	.39
SN74116N	24	1.49
SN74121N	14	.29
SN74122N	14	.45
SN74123N	16	.49
SN74125N	14	.45
SN74126N	14	.49
SN74128N	14	.49
SN74132N	14	.49
SN74136N	14	.69
SN74141N	16	.89
SN74142N	16	2.95
SN74143N	24	3.95
SN74144N	24	2.95
SN74145N	16	.65
SN74147N	16	1.69
SN74148N	16	.89
SN74150N	24	1.29
SN74151N	16	.29
SN74152N	14	.49
SN74153N	16	.39
SN74154N	24	1.25
SN74155N	16	.49
SN74156N	16	.65
SN74157N	16	.49
SN74158N	16	1.39
SN74159N	24	1.49
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SN74161N	16	.59
SN74162N	16	.85
SN74163N	16	.59
SN74164N	14	.69
SN74165N	16	.69
SN74166N	16	.69
SN74167N	16	2.95
SN74170N	16	1.59
SN74172N	24	4.95
SN74173N	16	.75
SN74174N	16	.59
SN74175N	16	.59
SN74176N	14	.89
SN74177N	14	.89
SN74179N	16	1.49
SN74180N	14	.69
SN74181N	24	1.95
SN74182N	16	.75
SN74184N	16	1.95
SN74185N	16	1.95
SN74189N	16	1.95
SN74190N	16	.89
SN74191N	16	.89
SN74192N	16	.69
SN74193N	16	.69
SN74194N	16	.79
SN74195N	16	.79
SN74196N	14	.99
SN74197N	14	.89
SN74198N	24	1.35
SN74199N	14	1.35
SN74221N	16	.89
SN74251N	16	.89
SN74273N	20	1.95
SN74276N	20	2.49
SN74279N	16	.59
SN74283N	16	1.39
SN74284N	16	2.95
SN74285N	16	2.95
SN74365N	16	.59
SN74366N	16	.59
SN74367N	16	.59
SN74368N	16	.59
SN74390N	16	1.49
SN74393N	14	1.49

74LS

Part No.	Pins	Price
74LS00	14	.19
74LS01	14	.19
74LS02	14	.19
74LS03	14	.19
74LS04	14	.25
74LS05	14	.25
74LS06	14	.99
74LS07	14	.99
74LS08	14	.19
74LS09	14	.19
74LS10	14	.19
74LS11	14	.19
74LS12	14	.19
74LS14	14	.39
74LS15	14	.29
74LS20	14	.19
74LS21	14	.25
74LS26	14	.25
74LS27	14	.25
74LS28	14	.29
74LS30	14	.19
74LS32	14	.25
74LS33	14	.39
74LS37	14	.29
74LS38	14	.29
74LS42	16	.39
74LS47	16	.89
74LS48	16	.89
74LS51	14	.25
74LS54	14	.19
74LS73	14	.35
74LS74	14	.25
74LS75	16	.29
74LS76	16	.29
74LS85	16	.49
74LS86	14	.25
74LS90	14	.39
74LS92	14	.49
74LS93	14	.39
74LS96	16	.49
74LS107	16	.35
74LS109	16	.35
74LS112	16	.29
74LS122	14	.45
74LS123	16	.49
74LS125	14	.39
74LS126	14	.39
74LS132	14	.39
74LS133	16	.49
74LS136	14	.39
74LS138	16	.39
74LS139	16	.39
74LS145	16	.89
74LS147	16	.99
74LS148	16	.99
74LS151	16	.39
74LS153	16	.39
74LS154	24	1.49
74LS155	16	.49
74LS156	16	.49
74LS157	16	.35
74LS158	16	.35
74LS160	16	.69
74LS161	16	.39
74LS162	16	.69
74LS163	16	.49
74LS164	14	.49
74LS165	16	.79
74LS166	16	.89
74LS168	16	.99
74LS169	16	.99
74LS170	16	1.49
74LS173	16	.49
74LS174	16	.39
74LS175	16	.39
74LS181	24	1.49
74LS189	16	3.95
74LS190	16	.49
74LS191	16	.49
74LS192	16	.69
74LS193	16	.69
74LS194	16	.59
74LS195	16	.59
74LS196	14	.89
74LS197	14	.89
74LS221	16	.59
74LS240	20	.69
74LS241	20	.69
74LS242	14	1.09
74LS243	14	.69
74LS244	20	.69
74LS245	20	.79
74LS247	16	.99
74LS251	16	.49
74LS253	16	.49
74LS257	16	.39
74LS258	16	.49
74LS259	16	1.19
74LS260	14	.49
74LS261	16	1.49
74LS266	14	.49
74LS273	20	.79
74LS279	16	.39
74LS280	14	1.19
74LS283	16	.59
74LS289	16	3.95
74LS299	20	1.49
74LS322	20	2.95
74LS323	20	2.49
74LS347	16	.79
74LS353	16	1.19
74LS364	20	1.95
74LS365	16	.39
74LS366	16	.39
74LS367	16	.39
74LS368	16	.39
74LS373	20	.79
74LS374	20	.79
74LS375	16	.69
74LS377	20	.79
74LS386	14	.45
74LS390	16	1.09
74LS393	14	.79
74LS399	16	1.09
74LS490	16	1.49
74LS533	20	1.95
74LS534	20	1.95
74LS540	20	1.09
74LS541	20	1.09
74LS590	16	5.95
74LS624	14	1.95
74LS629	16	2.49
74LS640	20	.99
74LS641	20	1.29
74LS644	20	1.29
74LS645	20	.99
74LS670	16	.99
74LS688	20	1.95
81LS95	20	1.49
81LS96	20	1.49
81LS97	20	1.49
81LS98	20	1.49

74S/PROMS*

Part No.	Pins	Price
74S00	14	.29
74S02	14	.29
74S04	14	.35
74S05	14	.35
74S08	14	.35
74S09	14	.39
74S10	14	.29
74S11	14	.35
74S15	14	.35
74S20	14	.35
74S22	14	.35
74S30	14	.35
74S32	14	.35
74S37	14	.69
74S38	14	.69
74S64	14	.39
74S65	14	.39
74S74	14	.49
74S85	16	1.49
74S86	14	.35
74S112	16	.49
74S124	16	2.75
74S132	14	1.49
74S133	16	.45
74S135	16	.89
74S136	14	1.39
74S138	16	.79
74S139	16	.79
74S140	14	.55
74S151	16	.79
74S153	16	.79
74S157	16	.79
74S158	16	.89
74S160	16	4.95
74S169	16	3.95
74S174	16	.79
74S175	16	.79
74S188*	16	1.75
74S189	16	1.95
74S194	16	1.49
74S195	16	1.49
74S196	16	1.49
74S240	20	1.49
74S241	20	1.49
74S242	14	2.69
74S244	20	1.49
74S251	16	.79
74S253	16	.79
74S257	16	.79
74S258	16	.99
74S273	20	2.39
74S280	14	1.89
74S287*	16	1.69
74S288*	16	1.69
74S299	20	3.95
74S373	20	1.69
74S374	20	1.69
74S472*	20	3.49

74ALS

Part No.	Pins	Price
74ALS00	14	.35
74ALS02	14	.35
74ALS04	14	.39
74ALS05	14	.39
74ALS08	14	.35
74ALS10	14	.35
74ALS27	14	.39
74ALS30	14	.35
74ALS32	14	.39
74ALS74	14	.55
74ALS109	16	.55
74ALS112	16	.79
74ALS138	16	.89
74ALS174	16	.89
74ALS175	16	.89
74ALS240	20	1.79
74ALS244	20	1.79
74ALS245	20	2.49
74ALS373	20	1.95
74ALS374	20	1.95
74ALS573	20	1.95

74F

Part No.	Pins	Price
74F00	14	.59
74F02	14	.59
74F04	14	.65
74F08	14	.59
74F10	14	.59
74F32	14	.65
74F74	14	.69
74F86	14	.89
74F109	16	.89
74F138	16	1.19
74F139	16	1.29
74F157	16	1.29
74F158	16	1.29
74F193	16	4.95
74F240	20	2.49
74F241	20	2.49
74F244	20	2.49
74F251	16	1.49
74F253	16	1.79
74F257	16	1.39
74F373	20	2.95
74F374	20	2.95
74F379	16	2.19

CD—CMOS

Part No.	Pins	Price
CD4000	14	.19
CD4001	14	.19
CD4002	14	.25
CD4006	14	.69
CD4007	14	.25
CD4008	16	.89
CD4009	16	.39
CD4010	16	.39
CD4011	14	.19
CD4012	14	.25
CD4013	14	.35
CD4014	16	.69
CD4015	16	.25
CD4016	14	.29
CD4017	16	.49
CD4018	16	.69
CD4019	16	.35
CD4020	16	.59
CD4021	16	.69
CD4022	16	.69
CD4023	14	.25
CD4024	14	.49
CD4025	14	.25
CD4026	16	1.49
CD4027	16	.39
CD4028	16	.65
CD4029	16	.65
CD4030	14	.39
CD4034	24	1.39
CD4035	16	.85
CD4040	16	.65
CD4041	14	.75
CD4042	16	.59
CD4043	16	.69
CD4044	16	.69
CD4046	16	.69
CD4047	14	.89
CD4048	16	.59
CD4049	16	.29
CD4050	16	.29
CD4051	16	.65
CD4052	16	.65
CD4053	16	.65
CD4056	16	2.19
CD4059	24	3.49
CD4060	16	.89
CD4066	14	.29
CD4068	14	.29
CD4069	14	.25
CD4070	14	.29
CD4071	14	.25
CD4072	14	.25
CD4073	14	.25
CD4075	14	.25
CD4076	16	.89
CD4077	14	.29
CD4078	14	.29
CD4081	14	.25
CD4082	14	.25
CD4093	14	.39
CD4094	16	1.49
CD4098	16	1.49
CD4099	16	1.39
CD40103	16	2.95
CD4503	16	.49
CD4508	24	1.45
CD4510	16	.69
CD4511	16	.69
CD4512	16	.69
CD4514	24	.99
CD4515	24	1.39
CD4516	16	.79
CD4518	16	.79
CD4519	16	.39
CD4520	16	.79
CD4522	16	.79
CD4526	16	.79
CD4528	16	.79
CD4529	16	1.49
CD4531	16	.89
CD4538	16	.89
CD4541	14	.89
CD4543	16	.99
CD4553	16	4.95
CD4555	16	.89
CD4556	16	.89
CD4560	16	3.95
CD4566	16	1.95
CD4583	16	1.19
CD4584	14	.59
CD4585	16	.75
CD4723	16	1.19
CD4724	16	1.19
MC14411	24	9.95
MC14490P	16	4.49
MC14572	16	.89

SPECIAL!! SPECIAL!! SPECIAL!!



MOTOROLA MC68701 — Microcomputer with EPROM

The MC68701 is an 8-bit single chip microcomputer unit (MCU) which significantly enhances the capabilities of the MC6800 family of parts. On-chip resources include 2048 bytes of EPROM, 128 bytes of RAM, Serial Communications Interface (SCI), parallel I/O, and a three function Programmable Timer.

MC68701. . . . . $24.95

CUSTOM COMMODORE CHIPS for VIC-20, C-64 and C-128 Personal Computers

Part No.	Description	Price	Part No.	Description	Price	Part No.	Description	Price
*6510	CPU	$19.95	*6526	CIA	$25.95	*6581	SID	$32.95
*6525	TPI	$20.95	*6560	VIC-I	$29.95	82S100PLA	PLA	$37.95
			*6567	VIC-II	$44.95			

*SPECS. AVAILABLE @ $1.50 EA. NOTE: 82S100 = U17 (C-64)

MICROPROCESSOR COMPONENTS

MICROPROCESSOR CHIPS

Part No.	Pins	Function	Price
D765AC	40	Floppy Disk Controller	4.95
CDP1802CE	40	CPU 2.5MHz	9.95
2661-3	28	Enhanced Prog. Comm. Interface	6.95
D3242	28	Addr. Multiplexer & Refresh Counter	6.95
Z80, Z80A, Z80B, SERIES			
Z80	40	CPU (MK3880N)(780C)2.5MHz	1.75
Z80-CTC	28	Counter Timer Circuit	1.79
Z80-DART	40	Dual Asynchronous Rec./Trans.	4.95
Z80-DMA	40	Direct Memory Access Circuit	4.95
Z80P10	40	Parallel I/O Interface Controller	1.79
Z80-S10/0	40	Serial I/O (TxCB and RxCB Bonded)	4.95
Z80-S10/1	40	Serial I/O (Lacks DTRB)	4.95
Z80-S10/2	40	Serial I/O (Lacks SYNCB)	4.95
Z80-S10/9	40	Serial I/O	4.95
Z80A	40	CPU (MK3880N-4)(780C-1) 4MHz	1.85
Z80A-CTC	28	Counter Timer Circuit	1.89
Z80A-DART	40	Dual Asynchronous Rec./Trans.	5.25
Z80A-DMA	40	Direct Memory Access Circuit	5.95
Z80A-P10	40	Parallel I/O Interface Controller	1.95
Z80A-S10/0	40	Serial I/O (TxCB and RxCB Bonded)	5.25
Z80A-S10/1	40	Serial I/O (Lacks DTRB)	5.25
Z80A-S10/2	40	Serial I/O (Lacks SYNCB)	5.25
Z80A-S10/9	40	Serial I/O	5.25
Z80B	40	CPU (MK3880N-6) 6MHz	3.95
Z80B-CTC	28	Counter Timer Circuit	4.95
Z80B-DART	40	Dual Asynchronous Rec./Trans.	6.95
Z80B-P10	40	Parallel I/O Interface Controller	4.95
Z80B-SIO/0	40	Ser. I/O (TxCB & RxCB Bond.) (MK3884-6)	12.95
Z80B-SIO/1	40	Serial I/O (Lacks DTRB)	12.85
Z80B-SIO/2	40	Serial I/O (Lacks SYNCB)	12.79
6500/6800/68000 SERIES			
6502	40	MPU with Clock (1MHz)	2.75
6502A	40	MPU with Clock (2MHz)	2.95
6502B	40	MPU with Clock (3MHz)	6.95
6520	40	Peripheral Inter. Adapter	2.95
6522	40	Versatile Inter. Adapter	4.95
6532	40	RAM I/O, Timer Array	6.49
6545	40	CRT Controller (CRTC)	4.95
6551	28	Async. Comm. Interface Adapt.	6.95
6800	40	MPU	1.95
6802	40	MPU with Clock and RAM	4.95
6809	40	CPU — 8-Bit (On-Chip Oscillator)	5.75
6809E	40	CPU — 8-Bit (External Clocking)	5.95
6810	24	128x8 Static RAM	1.95
68B10	24	128x8 Static RAM (2MHz)	3.49
6821	40	Peripheral Inter Adapt. (MC6820)	1.95
68B21	40	Peripheral Interface Adapter (2MHz)	3.95
6840	28	Programmable Timer	6.75
6843	40	Programmable Floppy Disk Controller	19.95
6845	40	CRT Controller (CRTC)	4.95
68B45	40	CRT Controller (CRTC) 2MHz	6.95
6850	24	Asynchronous Comm. Adapter	1.95
6852	24	Synchronous Serial Data Adapter	4.75
6860	24	0-600bps Digital MODEM	7.95
68000L8	64	MPU 16-Bit (8MHz)	9.95
68488P	40	General Purpose Int. Adapter	14.95
68661	28	Enhanced Prog. Comm. Interface (2661)	8.95
68701	40	Microcomputer with EPROM	24.95
8000/80000 SERIES			
8031	40	Control Oriented CPU w/RAM & I/O	6.95
8035	40	MPU — 8-Bit	1.95
8039	40	CPU — Sgl. Chip 8-Bit (128 bits RAM)	2.75
8060	40	CPU — 8-Bit NMOS	14.95
8073N	40	CPU w/Basic Micro Interpreter	29.95
8080A	40	CPU	3.95
8085A	40	CPU	2.75
8085A-2	40	CPU 8-Bit N-Channel (5MHz)	4.95
8086-2	40	CPU 16-bit 8MHz	8.95
8087	40	Arithmetic Processor (5MHz)	129.95
8087-2	40	Arithmetic Processor	139.95
8088	40	CPU 8/16-Bit	7.95
8116	18	Dual Baud Rate Generator	8.95
8155	40	HMOS RAM I/O Port-Timer	2.75
8156	40	RAM with I/O Port and Timer	2.75
8202	40	Dynamic RAM Controller	9.95
8203	40	64K Dynamic RAM Controller	29.95
8205	16	Hi Speed 1 out of 8 Binary Decoder	3.29
8212	24	8-Bit Input/Output (74S412)	1.95
8224	16	Clock Generator/Driver	2.25
8228	28	Sys. Cont./Bus Driver (74S428)	3.49
8237-5	40	High Perf. Prog. DMA Cont. (5MHz)	6.95
8238	28	System Controller (74S438)	4.29
8243	24	I/O Expander for 48 Series	2.49
8250A	40	Async. Comm. Element	6.95
8250B	40	ACE (IBM PC or XT Software Compatible)	5.95
8251	28	Prog. Comm. I/O (USART)	1.95
8251A	28	Prog. Comm. Interface (USART)	2.25
8253-5	24	Programmable Interval Timer	2.25
8254	24	Programmable Interval Timer	9.95
8255	40	Prog. Peripheral I/O (PPI)	1.95
8255A-5	40	Prog. Peripheral I/O (PPI) 5MHz	2.25
8257-5	40	Prog. DMA Controller	2.49
8259	28	Prog. Interrupt Control	2.25
8259-5	28	Prog. Interrupt Controller	2.49
8272	40	Sgle/Dble Density Floppy Disk Cont.	4.95
8274	40	Multi-Protocol Serial Cont. (7201)	14.95
8275	40	Prog. CRT Controller	14.95
8279	40	Prog. Keyboard/Display Interface	2.49
8279-5	40	Prog. Keyboard/Display Interface	2.95
8282	20	Octal Latch	3.95
8284	18	Clock Generator/Driver	2.95
8286	20	Octal Bus Transceiver	3.95
8287	20	Octal Bus Transceiver (Inverted)	3.95
8288	20	Bus Controller	4.95
8289	20	Bus Arbiter	14.95
8741	40	8-Bit Univ. Peripheral Interface	8.95
8748	40	HMOS EPROM MPU	7.95
8749	40	MPU 8-Bit (EPROM Version of 8049)	9.95
8751	40	CPU w/4Kx8 EPROM & 128x8 RAM	29.95
8755	40	16K EPROM with I/O	14.95
80186	68	High Integration 16-Bit MPU	49.95
80188	68	High Integra. 16-Bit MPU (8-Bit Data Bus)	49.95
80287	40	Numeric Processor Ext.	229.95

DYNAMIC RAMS

Part No.	Pins	Function		Price
1103	18	1024x1	(300ns)	.69
4027	16	4096x1	(250ns)	.89
4116N-15	16	16,384x1	(150ns)	.45
4116N-20	16	16,384x1	(200ns)	.39
4128	16	131,072x1	(200ns)	4.95
4164N-150	16	65,536x1	(150ns)	.89
4164N-200	16	65,536x1	(200ns)	.79
TMS4416-12	18	16,384x4	(120ns)	4.95
MM5261	18	1024x1	(300ns)	.25
MM5262	22	2048x1	(365ns)	.25
MM5270	18	4096x1	(250ns)	1.95
MM5280	22	4096x1	(200ns) 2107	1.95
MM5298-3	16	8192x1	(200ns)	.19
8118	16	16,384x1	(120ns)(+5V Only Req)	1.95
41256-150	16	262,144x1	(150ns)	3.29
41256-200	16	262,144x1	(200ns)	3.19
50464-15	18	65,536x4	(150ns)(41254)(41464)	7.95

STATIC RAMS

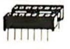
Part No.	Pins	Function		Price
TMM2016-12	24	2048x8	(120ns)	1.69
2101	22	256x4	(450ns) 8101	1.95
2102	16	1024x1	(350ns)	.89
2102-2L	16	1024x1	(250ns) L.P. (91L02)	1.49
2111	18	256x4	(450ns) 8111	2.49
2112	16	256x4	(450ns) MOS	2.49
2114N	18	1024x4	(450ns)	.99
2114N-L	18	1024x4	(450ns) L.P.	1.09
2114N-2	18	1024x4	(200ns)	1.05
2114N-2L	18	1024x4	(200ns) L.P.	1.49
21C14	18	1024x4	(200ns) (CMOS)	.49
2116N-25L	24	2048x8	(250ns) L.P. NMOS	3.49
2125A	16	1024x1	(45ns) High Speed	2.95
2147HN	18	4096x1	(70ns)	3.95
2148HN	18	1024x4	(70ns)	4.29
2149	18	1024x4	(45ns)	4.95
27LS00	16	256x1	(80ns) L.P.	2.95
TMS4047-45	20	1024x4	(450ns)	.99
5101	22	256x4	(450ns) CMOS	3.95
MM5257	18	4096x1	(450ns) 4044	2.95
HM6116P-3	24	2048x8	(150ns) CMOS	1.79
HM6116LP-3	24	2048x8	(150ns) L.P. CMOS	1.85
HM6116P-4	24	2048x8	(200ns) CMOS	1.69
HM6116LP-4	24	2048x8	(200ns) L.P. CMOS	1.75
HM6264P-12	28	8192x8	(120ns) CMOS	4.69
HM6264LP-12	28	8192x8	(120ns) L.P. CMOS	4.79
HM6264P-15	28	8192x8	(150ns) CMOS	4.49
HM6264LP-15	28	8192x8	(150ns) L.P. CMOS	4.59
6514	18	1024x4	(350ns) CMOS (UPD444C)	4.49
74S189	16	16x4	(35ns)	1.95
74S289	16	16x4	(35ns) 3101	2.95

PROMS/EPROMS

Part No.	Pins	Function		Price
1702A	24	256x8	(1μs)	3.95
TMS2516	24	2048x8	(450ns)	3.49
TMS2532	24	4096x8	(450ns) NMC2532	3.95
TMS2564	28	8192x8	(450ns)	8.95
2708	24	1024x8	(450ns)	3.95
TMS2716	24	2048x8	(450ns) 3 voltage	6.49
2716	24	2048x8	(450ns)	2.49
27C16	24	2048x8	CMOS	9.95
2716-1	24	2048x8	(350ns)	2.95
2732	24	4096x8	(450ns)	2.49
2732A-20	24	4096x8	(200ns) 21V	3.95
2732A-25	24	4096x8	(250ns) 21V	2.95
2732A-45	24	4096x8	(450ns) 21V	2.75
27C32	24	4096x8	CMOS	10.95
2758	24	1024x8	(450ns) Single +5V	3.95
2764-20	28	8192x8	(200ns) 21V	3.95
2764-25	28	8192x8	(250ns) 21V	2.95
2764A-25	28	8192x8	(250ns) 12.5V	2.95
2764-45	28	8192x8	(450ns) 21V	2.19
27C64	28	8192x8	CMOS 21V	6.95
27128-25	28	16,384x8	(250ns) 128K 21V	2.95
27128A-25	28	16,384x8	(250ns) 128K 12.5V	4.95
27256-25	28	32,768x8	(250ns) 256K (14V)	7.95
27C256-25	28	32,768x8	(250ns) 256K (CMOS)	13.95
68764	24	8192x8	(450ns) 25V	15.95
68766	24	8192x8	(350ns) 25V	16.95
74S188	16	32x8	PROM O.C. (6330-1)	1.75
74S287	16	256x4	PROM T.S. (6301-1)	1.69
74S288	16	32x8	PROM T.S. (6331-1)	1.69
74S387	16	256x4	PROM O.C. (6300-1)	1.69
74S471	20	256x8	PROM T.S. (6309-1)	4.95
74S472	20	512x8	PROM T.S. (6349-1)	3.49
74S473	20	512x8	PROM O.C. (6348)	2.95
74S474	24	512x8	PROM T.S. (DM87S296N)	3.49
74S475	24	512x8	PROM O.C. (6340)	3.49
74S476	18	1024x4	PROM T.S.	4.95
74S570	16	512x4	PROM O.C. (6305)	2.95
74S571	16	512x4	PROM T.S. (6306)	2.95
74S572	18	1024x4	PROM O.C. (6352)	3.49
74S573	18	1024x4	PROM T.S. (82S137)	2.95
82S23	16	32x8	PROM O.C. (27S18)	2.49
82S115	24	512x8	PROM T.S. (27S15)	9.95
82S123	16	32x8	PROM T.S. (27S19)	2.95
82S126	16	256x4	PROM O.C. (27S20)	2.95
82S129	16	256x4	PROM T.S. (27S21)	2.95
82S130	16	512x4	PROM O.C. (27S12)	3.95
82S185	18	2048x4	PROM T.S. (TBP24S81)	9.95
82S191	24	2048x8	(80ns)	14.95
DM87S181N	24	1024x8	PROM T.S. (82S181)	9.95

DATA ACQUISITION

Part No.	Pins	Function	Price
ADC0800	18	8-Bit A/D Converter (±1 LSB)	14.49
ADC0801	20	8-Bit A/D Converter (1/4LSB)	14.95
ADC0803	20	8-Bit A/D Converter (±1/2LSB)	5.95
ADC0804	20	8-Bit A/D Converter (1LSB)	3.49
ADC0808	28	8-Bit A/D Conv. w/8-Channel Analog	8.95
ADC0809	28	8-Bit A/D Converter (8-Ch. Multi.)	3.95
ADC0816	40	8-Bit A/D Conv. w/16-Channel Analog	14.95
ADC0817	40	8-Bit A/D Converter (16-Ch. Multi.)	8.95
ADC0832	8	8-Bit Ser. I/O A/D Conv. (2,4, or 8-Ch. Mult.)	4.95
DAC0800	16	8-Bit D/A Converter (±1 LSB)	3.95
DAC0806	16	8-Bit D/A Converter (0.78% Lin.)	1.95
DAC0807	16	8-Bit D/A Converter (MC1408-7)	1.49
DAC0808	16	8-Bit D/A Converter (MC1408-8)	1.95
DAC0830	20	8-Bit Up D/A Conv. (.05% Lin.)	5.95
DAC0831	20	8-Bit Up D/A Conv. (.10% Lin.)	4.49
DAC1000	24	10-Bit D/A Conv. Micro. Comp. (0.05%)	4.95
DAC1008	20	8-Bit D/A Conv. Micro. Comp. (0.20%)	7.95
DAC1022	16	10-Bit D/A Conv. (0.20% lin.)	5.95
DAC1222	18	12-Bit D/A Conv. (0.20% Lin.)	6.95
DAC1230	20	12-Bit Up D/A Conv. (.012% Lin.)	14.95
DAC1231	20	12-Bit Up D/A Conv. (.024% Lin.)	13.95
AY-3-1015D	40	25K Baud UART	4.95
AY-5-1013A	40	30K Baud UART (TR1602)	3.95



Low Profile (Tin) Sockets

Part No.	1-9	10-99	100-up
8 pin LP	.13	.12	.11
14 pin LP	.15	.13	.11
16 pin LP	.17	.15	.13
18 pin LP	.25	.23	.21
20 pin LP	.28	.26	.23
22 pin LP	.30	.28	.26
24 pin LP	.31	.30	.29
28 pin LP	.39	.37	.35
40 pin LP	.49	.46	.43



Soldertail (Gold) Standard

Part No.	1-9	10-99	100-up
8 pin SG	.39	.35	.29
14 pin SG	.49	.45	.39
16 pin SG	.55	.49	.45
18 pin SG	.65	.59	.51
20 pin SG	.75	.65	.59
22 pin SG	.79	.69	.65
24 pin SG	.79	.69	.65
28 pin SG	.95	.85	.75
36 pin SG	1.25	1.15	.99
40 pin SG	1.39	1.25	1.15



Wire Wrap Sockets (Gold) Level #3

Part No.	1-9	10-99	100-up
8 pin WW	.55	.49	.45
10 pin WW	.65	.59	.55
14 pin WW	.69	.65	.59
16 pin WW	.75	.69	.65
18 pin WW	.85	.79	.75
20 pin WW	.95	.89	.85
22 pin WW	.99	.95	.89
24 pin WW	1.19	1.09	.99
28 pin WW	1.39	1.29	1.19
36 pin WW	1.49	1.39	1.29
40 pin WW	1.79	1.69	1.59



Header Plugs (Gold)

Part No.	1-9	10-99	100-up
14 pin HP	.55	.49	.45
16 pin HP	.59	.55	.49
24 pin HP	.99	.89	.79

Header Covers

Part No.	1-9	10-99	100-up
14 pin HC	.15	.13	.12
16 pin HC	.19	.17	.15
24 pin HC	.29	.27	.25

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EEPROM

Part No.	Pins	Function	Price
2816A	24	2048x8 16K E²PROM 350ns.	**$8.95**

Features: • On-board Address/Data Latches • Auto-Timed Byte Write (on chip timer) • 5V Erase/Write/Read • Optional High Voltage Erase/Program (9V-15V) • Power Up/Down Write Protection • Auto Erase before Write

The 2816A is an ideal nonvolatile memory providing in-system alterability with the same ease and with the same features as 2Kx8 Static RAMs.

Digitalker™

DT1050— Applications: Teaching aids, appliances, clocks, automotive, telecommunications, language translations, etc. The DT1050 is a standard DIGITALKER kit encoded with 137 separate and useful words, 2 tones, and 5 different silence durations. The words and tones have been assigned discrete addresses, making it possible to output single words or words concatenated into phrases or even sentences. The "voice" output of the DT1050 is a highly intelligible male voice. The DT1050 consists of a Speech Processor Chip, MM54104 (40-pin) and two (2) Speech ROMs MM52164SSR1 and MM52164SSR2 (24-pin) along with a Master Word list and a recommended schematic diagram on the application sheet.

DT1050 Digitalker™. . . . . $24.95 ea.
MM54104 Processor Chip. . . . . $12.95 ea.

DT1057—Expands the DT1050 vocabulary from 137 to over 260 words. Incl. 2 ROMs and specs.
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INTERSIL

Part No.	Pins	Function	Price
FE0202D	40	4 Digit LCD Display for 7211IPL & 7211MIPL	12.95
FE0203D	40	3½ Digit LCD Display for 7106 & 7116	12.95
7045IPI	28	CMOS Precision Timer	11.95
7045EV/Kit	28	Stopwatch Chip, XTL (Evaluation Kit)	16.95
7106CPL	40	3½ Digit A/D (LCD Drive)	8.95
7106EV/Kit	40	IC, Circuit Board, Display (Evaluation Kit)	46.95
7107CPL	40	3½ Digit A/D (LED Drive)	8.95
7107EV/Kit	40	IC, Circuit Board, Display (Evaluation Kit)	46.95
7116CPL	40	3½ Digit A/D LCD Dis. HLD	8.95
7201IUS		Low Battery Volt. Indicator	2.29
7205IPG	24	CMOS LED Stopwatch/Timer	14.95
7205EV/Kit	24	Stopwatch Chip, XTL (Evaluation Kit)	16.95
7206CJPE	16	Tone Generator	4.95
7206CEV/Kit	16	Tone Generator Chip, XTL (Evaluation Kit)	7.95
7207AIPD	14	Oscillator Controller	5.95
7207AEV/Kit	14	Freq. Counter Chip, XTL (Evaluation Kit)	8.49
7211IPL	40	4 Digit LCD Display Decoder/Driver (TTL compatible)	7.95
7211MIPL	40	4 Digit LCD Display Decoder/Driver (Microproc. compat.)	8.49
7215IPG	24	4 Func. CMOS Stopwatch CKT	16.95
7215EV/Kit	24	4 Func. Stopwatch Chip, XTL (Evaluation Kit)	19.49
7216AIJI	28	8 Digit Univ. Counter C.A.	31.49
7216DIPI	28	8 Digit Freq. Counter C.C.	21.49
7217IJI	28	4 Digit LED Up/Down Counter C.A.	10.95
7217AIPI	28	4 Digit LED Up/Down Counter C.C.	8.95
7224IPL	40	LCD 4½ Digit Up Counter DRI	10.95
7226AEV/Kit	40	5 Function Counter Chip, XTL (Evaluation Kit)	99.95

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74HC HIGH SPEED CMOS

Part No.	Pins	Price
74HC00	14	.35
74HC02	14	.39
74HC03	14	.39
74HC04	14	.39
74HCU04	14	.39
74HC08	14	.39
74HC10	14	.39
74HC11	14	.39
74HC14	14	.59
74HC20	14	.39
74HC27	14	.39
74HC30	14	.39
74HC32	14	.45
74HC42	16	.75
74HC51	14	.39
74HC58	14	.39
74HC73	14	.45
74HC74	14	.45
74HC75	16	.69
74HC76	16	.69
74HC85	16	1.19
74HC86	14	.59
74HC107	14	.49
74HC109	16	.49
74HC112	16	.49
74HC123	16	1.19
74HC125	14	.99
74HC132	14	.79
74HC133	16	1.19
74HC138	16	.79
74HC139	16	.79
74HC147	16	.99
74HC151	16	.79
74HC153	16	.79
74HC154	24	1.95
74HC157	16	.79
74HC158	16	.79
74HC160	16	.89
74HC161	16	.89
74HC162	16	.89
74HC163	16	.89
74HC164	14	.99
74HC165	16	1.49
74HC166	16	1.95
74HC173	16	.89
74HC174	16	.89
74HC175	16	.89
74HC190	16	1.19
74HC191	16	1.19
74HC192	16	.99
74HC193	16	.99
74HC194	16	.89
74HC195	16	.89
74HC221	16	1.95
74HC237	16	1.19
74HC240	20	1.39
74HC241	20	1.39
74HC242	14	1.39
74HC243	14	1.39
74HC244	20	1.49
74HC245	20	1.59
74HC251	16	.79
74HC253	16	.79
74HC257	16	.79
74HC259	16	1.19
74HC266	14	.69
74HC273	20	1.79
74HC280	14	2.95
74HC299	20	3.19
74HC366	16	1.49
74HC367	16	1.49
74HC373	20	1.49
74HC374	20	1.49
74HC390	16	1.19
74HC393	14	1.19
74HC533	20	1.95
74HC534	20	1.95
74HC595	16	1.95
74HC688	20	1.95
74HC4024	14	1.19
74HC4040	16	1.19
74HC4049	16	.79
74HC4050	16	.79
74HC4060	16	1.19
74HC4075	14	.49
74HC4078	14	.49
74HC4511	16	1.95
74HC4514	24	2.95
74HC4538	16	1.95
74HC4543	16	2.95

74HCU04 is unbuffered.

74C—C/MOS

Part No.	Pins	Price
74C00	14	.29
74C02	14	.29
74C04	14	.25
74C08	14	.35
74C10	14	.29
74C14	14	.49
74C20	14	.29
74C30	14	.29
74C32	14	.35
74C42	16	.89
74C48	16	1.19
74C73	14	.49
74C74	14	.49
74C85	16	1.19
74C86	14	.29
74C89	16	3.95
74C90	14	.89
74C93	14	.89
74C95	14	.99
74C107	14	.55
74C151	16	1.95
74C154	24	2.95
74C157	16	1.75
74C160	16	.89
74C161	16	.89
74C162	16	.89
74C163	16	.89
74C164	14	.99
74C165	16	.99
74C173	16	.89
74C174	16	.89
74C175	16	.89
74C192	16	.99
74C193	16	.99
74C195	16	.99
74C221	16	1.19
74C240	20	1.59
74C244	20	1.59
74C373	20	1.95
74C374	20	1.95
74C901	14	.49
74C902	14	.49
74C903	14	.49
74C906	14	.49
74C907	14	.59
74C911	28	7.95
74C912	28	7.95
74C915	18	1.19
74C917	28	7.95
74C920	22	9.95
74C921	18	9.95
74C922	18	3.95
74C923	20	3.95
74C925	16	4.95
74C926	18	4.95
74C930	18	9.95
80C95	16	.69
80C97	16	.69

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Part No.	Pins	Price
DS0026CN	8	1.69
TL064CN	14	1.95
TL071CP	8	.59
TL072CP	8	.79
TL074CN	14	.79
TL081CP	8	.49
TL082CP	8	.69
TL084CN	14	1.09
LM109K		4.95
LM301CN	8	.35
LM302H		.69
LM304H		.99
LM305H		.99
LM307CN	8	.45
LM308CN	8	.59
LM309K		1.25
LM310CN	8	1.29
LM311CN	8	.45
LM312H		1.49
LM317T		.99
LM317K		2.95
LM318CN	8	1.19
LM319N	14	1.19
LM320K-5		1.35
LM320K-12		1.35
LM320K-15		1.35
LM320K-24		1.35
LM320T-5		.59
LM320T-12		.59
LM320T-15		.59
LM320T-24		.59
LM322N	14	1.49
LM323K		4.49
LM324N	14	.39
LM329DZ		.55
LM331M	8	3.49
LM334Z		1.19
LM335Z		1.29
LM336Z		1.09
LM337MP		1.15
LM337T		1.49
LM338K		3.95
LM339N	14	.49
LM340K-5		1.35
LM340K-12		1.35
LM340K-15		1.35
LM340K-24		1.35
LM340T-5		.49
LM340T-12		.49
LM340T-15		.49
LM340T-24		.49
LF347N	14	.99
LM348N	14	.69
LM350K		3.95
LF351N	8	.49
LF353N	8	.59
LF355N	8	.89
LF356N	8	.89
LM358N	8	.49
LM359N	14	1.59
LM360N	8	2.19
LM361N	14	1.59
LM370N	14	4.95
LM373N	14	4.95
LM377N	14	1.95
LM380CN	8	1.09
LM380N	14	.89
LM381N	14	1.29
LM382N	14	1.29
LM384N	14	1.69
LM386N-3	8	.69
LM387N	8	.99
LM389N	18	.99
LM391N-80	16	1.29
LM392N	8	.59
LM393N	8	.45
LF398N	8	2.39
LM399H		3.95
LF412CN	8	1.49
TL494CN	16	1.95
TL496CP	8	1.59
TL497ACN	14	2.19
NE531V	8	1.79
NE540H (C540H)		2.95
NE544N	14	1.49
NE555V	8	.29
XR-L555	8	.69
LM556N	14	.59
NE558N	16	1.19
NE564N	16	1.95
LM565N	14	.99
LM566CN	8	1.39
LM567V	8	.89
NE570N	16	2.49
NE571N	16	1.95
NE592N	14	.89
LM710N	14	.69
LM711N	14	.69
LM723N	14	.45
LM733N	14	.69
LM739N	14	2.95
LM741CN	8	.29
LM747N	14	.59
LM748N	8	.59
UA760HC		1.29
LM1456V	8	1.95
LM1458CN	8	.49
LM1488N	14	.69
LM1489N	14	.69
LM1496N	14	.99
LM1605CK		9.95
LM1871N	18	1.95
LM1872N	18	2.49
LM1877N-9	14	2.49
LM1889N	18	1.59
LM1896N	14	1.59
LM2002T		1.95
ULN2003A	16	.99
XR2206	16	3.95
XR2207	14	2.49
XR2208	16	1.79
XR2211	14	2.95
LM2877P		1.95
LM2878P		2.19
LM2901N	14	.59
LM2902N	14	.59
LM2907N	14	1.95
LM2917N	8	1.55
LM2935T		1.49
LM3900N	14	.59
LM3905CN	8	1.19
LM3909N	8	.89
LM3911N	8	1.19
LM3914N	18	1.95
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RC4193NB	8	2.95
LM4250CN	8	1.19
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LM13080N	8	1.19
LM13600N	16	1.19
75477	8	1.19
76002	14	1.25
76477	28	3.95

30003 1982 Nat. Linear Data Book (1952 pgs.) **. . $14.95**

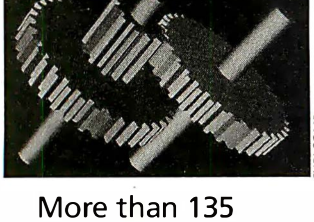
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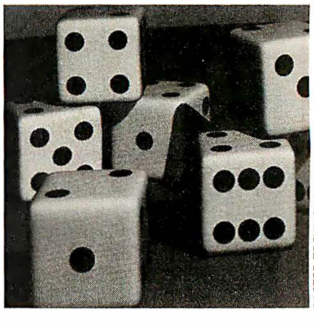
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AUTOMATION IN ORGANIC SYNTHESIS

BY GARY W. KRAMER AND PHILIP L. FUCHS

In search of the electronic chemist

THIS ARTICLE WILL cover aspects of how we are automating the research process for organic chemical synthesis. We use a robot arm to handle the mechanical aspects of the task (such as preparing samples) and a number of independent, microprocessor-based substations for support activities (such as cleaning the sample tubes and controlling the analysis equipment). We'll explain in detail how we are interfacing support equipment to one of the substations.

In the day-to-day life of the scientist there are occasional periods of great excitement, but more often the practice of experimental science is routine. Many times procedures are repeated with only small variations to determine the effect of variables or to gather enough data for sound statistical analyses. Organic chemistry is no exception.

Production of a target molecule, whether a drug, a natural product, or an industrial chemical, often requires carrying out a sequence of steps where the product from the current reaction becomes the starting material for the next step. Like all serial processes, synthesis schemes are adversely affected by weak links. Considerable effort is expended to improve the low-yielding steps of the process.

In the commercial production of chemicals, it is desirable to know the precise effects of variables on reaction rate and yield. This knowledge is important in compensating for unforeseen events that can affect production, safety, and economics. When the number of variables is large, the number of experiments needed to find the best set of conditions or to map out a reaction profile can be astronomical.

Automation is an answer to this problem. In other branches of chemistry, most notably clinical chemistry, automation of routine processes is common. In organic chemistry, where experimental procedures are more diverse, automation is not widespread. If automation is to come to the organic laboratory, it must be flexible enough to allow facile experimental reconfigurations.

The introduction of the Zymate Laboratory Robot in 1981 by the Zymark Corporation (see the "Products Mentioned" text box on page 268) greatly enhanced the practicality of automating organic synthesis. The Zymark robot consists of a nonmobile, nonarticulated arm that can rotate about its base, can be raised or lowered, and can move in and out to gain access to a cylindrical work area about 14 inches high and 54 inches in diameter. At the end of the arm is a wrist that can rotate 360 degrees. A unique feature of this robotic arm is its set of hands. Several different hand types (gripper, syringe, etc.) are available, and the robot can be programmed to change hands for different applications. A self-contained system controller and a variety of automated laboratory appliances (centrifuge, balance, shaker, vortexer,

(continued)

Gary W. Kramer holds a Ph.D. from Purdue University and is an instrumentation specialist with Purdue's Department of Chemistry. Philip L. Fuchs is a professor of chemistry at Purdue; he has a Ph.D. from the University of Wisconsin. They can both be reached at the Department of Chemistry, Purdue University, West Lafayette, IN 47901.

syringe pumps, etc.) complete a typical laboratory system.

THE FIRST-GENERATION SYSTEM

Although the Zymark system was created to do chemistry, it was designed with the sample preparation phase of analytical chemistry in mind. Accordingly, it was given the capabilities of weighing, mixing, diluting, pipetting, and extracting: tasks necessary to get a raw sample ready for final analyses by other instruments. Initially, we built our system around the robot, using it to do everything. However, as the system's capability has expanded, our philosophy has evolved to using the robot only to handle situations that would otherwise be difficult to automate.

The creation of new instrumentation often goes through several stages. First, a demonstration system is created, which performs some subset of the overall task. Its purpose is to answer key feasibility questions, highlight troublesome areas, and attract resources to the project. Our first-generation scheme consisted of a Zymark system, locally built automated room temperature reactors, and a semiautomated liquid chromatograph as the analyzer (see photo 1). The system was managed solely by the Zymark controller. The first chemical reaction tested was chosen not only because it fit the system capabilities but also because it was a step in a synthesis in need of yield improvement. The system was run open-loop; that is, the results from the reactions were printed out for later interpretation by the operator. This system ran 16 reactions and 240 analyses over a 50-hour period, producing a significant improvement in the yield of the desired material (see the article "Robotic Orchestration of Organic Reactions" by A. R. Frisbee, M. H. Nantz, G. W. Kramer, and P. L. Fuchs in the *Journal of the American Chemical Society*, volume 106, page 7143, 1984).

TOWARD THE SECOND GENERATION

Change is inevitable in creating open-ended systems such as ours, as to-

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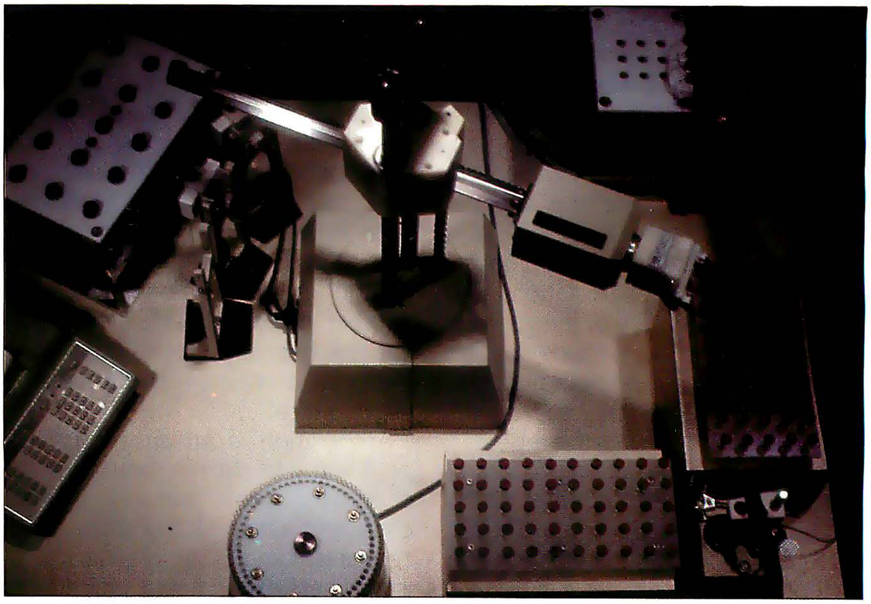


Photo 1: *The Purdue Automated Synthesis System, phase 1. The robot arm stands in the center of the laboratory setup. Arranged around the arm, starting from bottom left of the photo and continuing clockwise are: HP3390A reporting integrator, reagent station, reactor station, aliquot archive station, workup station, syringe and needle wash station, and sample turntable. In front of the reagent station are three hand parking stations.*

day's wants become tomorrow's needs. Accommodating this change is a major design challenge. Flexibility, modularity, and portability in both software and hardware are essential.

The control-system architecture (figure 1) reflects these design criteria and allows orderly growth. The executive processor contains the user interface, application program, and the main control routines. It interacts with the rest of the system through 8-bit managerial processors. These managers are the key to the control system. They serve as buffers, translators, controllers, and isolators. Interprocessor communication is carried out in a block protocol over serial data lines. This architecture allows true concurrency while freeing the system from timing constraints. Its modularity permits replacement of system components with a minimum of problems. Isolation of the executive from the real-time, bit-flipping environment of the managers allows the application software to be written in a portable high-level language.

The analysis manager provides a good example of the managerial function. Most modern chemical analysis equipment is smart; that is, its internal control systems are processor-driven. Many of these instruments allow downloading of analytical methods, automatic sample injection, postprocessing of raw data into meaningful information, and transmission of results. In our work, a sample is loaded into the instrument's autoinjector by the robot, a command file detailing the processing is downloaded, and, following the analysis, the instrument returns the results.

Unfortunately, there is little standardization in the world of analytical instruments. Even within a given company's product line, the command to inject a sample on a high-pressure liquid chromatograph (HPLC) is not likely to be the same as that used on a gas chromatograph (GC). However, the managerial computer will know these details, so they can remain hidden from both the user and the application-level software.

Actual analytical parameters are specified by the user during system initialization and are stored as

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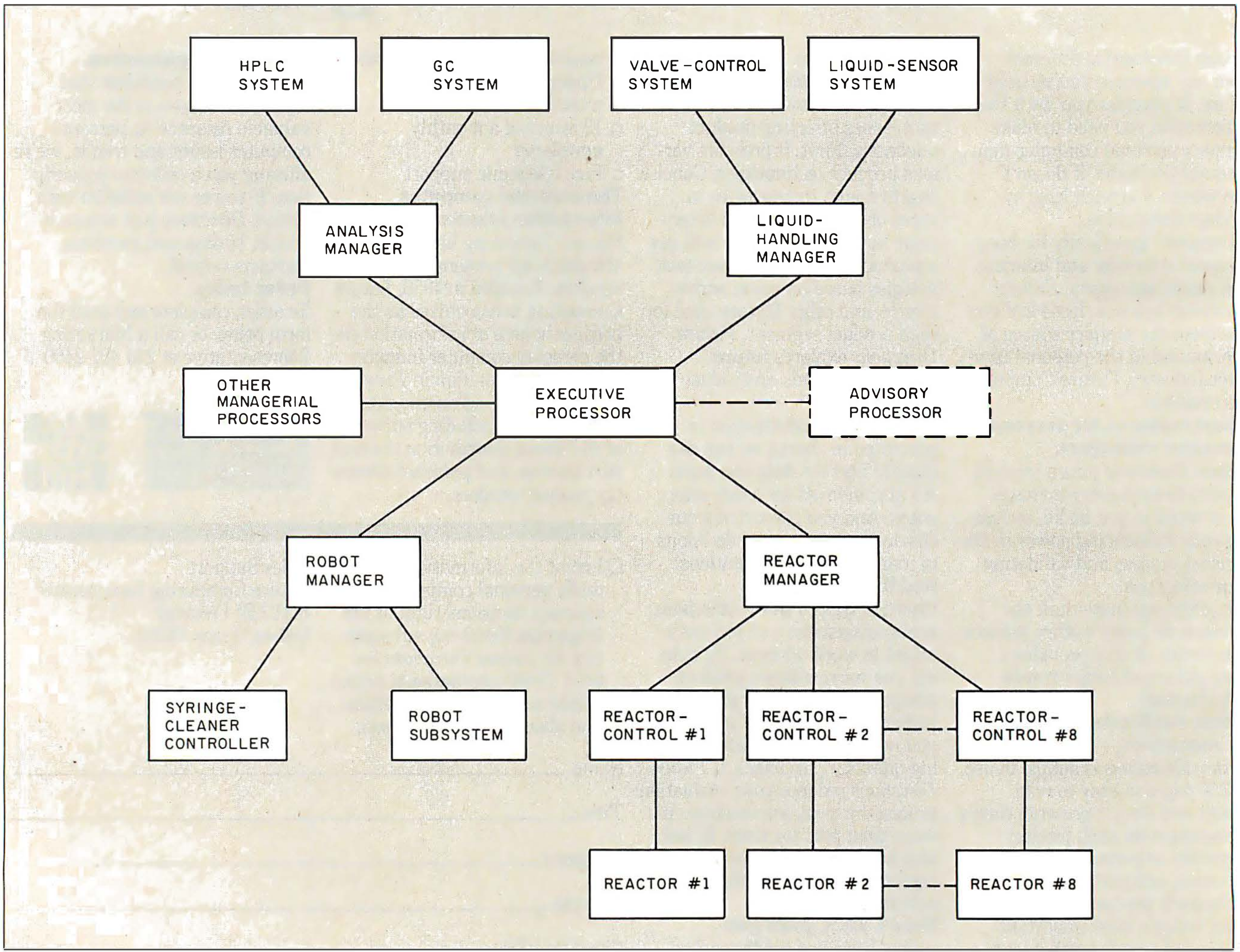


Figure 1: *Control-system architecture.*

AW . . .
WHAT THE HECK!

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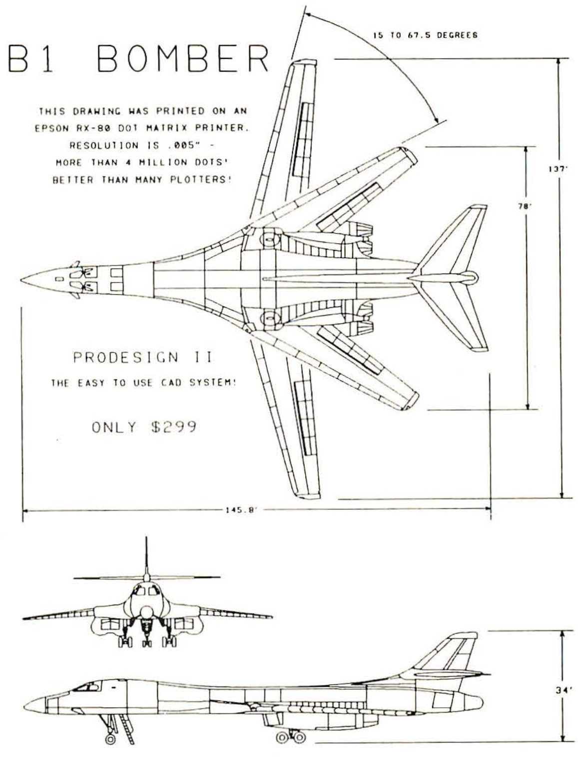
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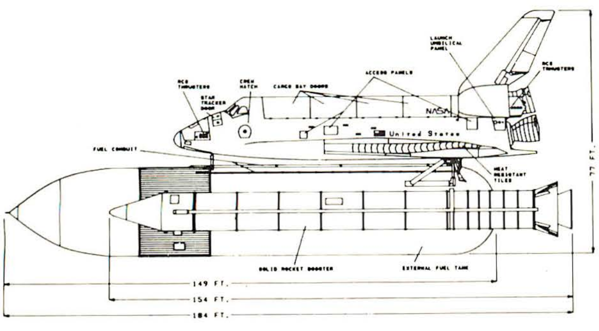
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methods files that are downloaded to the analytical manager at run time. During a run the executive can issue a task to the manager, such as "Take sample number three and run an HPLC analysis using method number two." Upon receiving this command, the manager checks to see if the task can be done (analytical instrument ready and sample three exists) and then returns a completion time estimate to the executive, which sets up a watchdog timer. The manager carries out this task by delivering the necessary directives to the analytical instrument.

When the results of the analysis are available and formatted for transmission to the managerial computer, it interrupts the executive. Uploading the results to the executive completes the task. If the executive watchdog times out, the executive will issue a status request to the manager and will initiate appropriate action based upon the returned status. Fault conditions in the analytical instruments are reported to the manager, which either corrects the problem or passes it up to the executive. In this way, a disparate collection of analyzers can be made to look relatively uniform to the application software.

Figure 1 shows an advisory processor in a dotted box to the right of the executive processor. In the future, we will probably use an expert system and other artificial intelligence (AI) methods to enhance the capabilities of our system. Since this technology usually requires special hardware and software environments, a separate computer seems appropriate.

Initially, the AI machine will function as a consultant to the executive, but in time the user interface and application programming functions may migrate to this processor.

Choosing the Components

Requirements for flexibility, modularity, and expansibility point to a multicard, bus-oriented system. Our choice of the IEEE-696 (S-100) bus over Multibus or STD-bus systems was

(continued)

Products Mentioned

Laboratory Robot
ZYMARK CORPORATION
Zymark Center
Hopkinton, MA 01748
(617) 435-9501

Chemically Inert Metering Pumps
FLUID METERING INC.
29 Orchard St.
Oyster Bay, NY 11771
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LQD Liqua Sense Liquid Level Sensor
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Electronics Division
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Windsor Locks, CT 06096
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Liquid Level Quartz Sensor
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Optical Liquid Detector
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North Springfield, VT 05150

S19 Sight Glass Scanner
SKAN-A-MATIC CORPORATION
Route 5W
Elbridge, NY 13060
(315) 689-3961

Bantam-meter Optical Sensor
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Spruce St.
Vineland, NJ 08360
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Fields Per File	Unlimited	128	400
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finally made on the basis of cost per board function and the authors' familiarity with S-100 systems. With the bus architecture decided, the choice of a CompuPro 8/16 was easy. At present, CP/M is the base-level operating system. However, only the terminals, printer, and disks are CP/M system devices. The special interrupt-driven, multitasking control software is implemented as a transient program. This run-time package takes control of the executive processor, relying on CP/M only for terminal and disk I/O (input/output) handling.

If the choice of the executive processor was easy, the converse was true of the managers. Many of the executives' requirements also apply to the managers. But the managers only need to be 8-bit ROM (read-only memory)-based machines; disks and operating systems are unnecessary. The choice came down to either an STD-bus approach or an in-house designed system. Over the years we have built up an extensive 8-bit system that has been used in several data acquisition and control projects. To aid in the development and maintenance of this system, we also created a variety of hardware and software tools. We have little experience with the STD bus; however, it is desirable to use commercially available equipment whenever possible. Ultimately, we chose the in-house design for our first synthesis system, feeling that we could get going quicker with it.

Each managerial computer contains the same set of core boards: an 8085 8-bit microprocessor with 19 interrupt channels, a status and start-up card containing bootstrap PROM (programmable read-only memory) used during initialization, a real-time clock card containing a day/date clock (MM58167) and six 16-bit timers (two 8253s), a triple serial interface card (three 2651s), and a 64K-byte PROM/RAM (random-access read/write memory) card. Other cards, such as buffered parallel interfaces, additional clock cards, analog-to-digital converter cards, digital-to-analog con-

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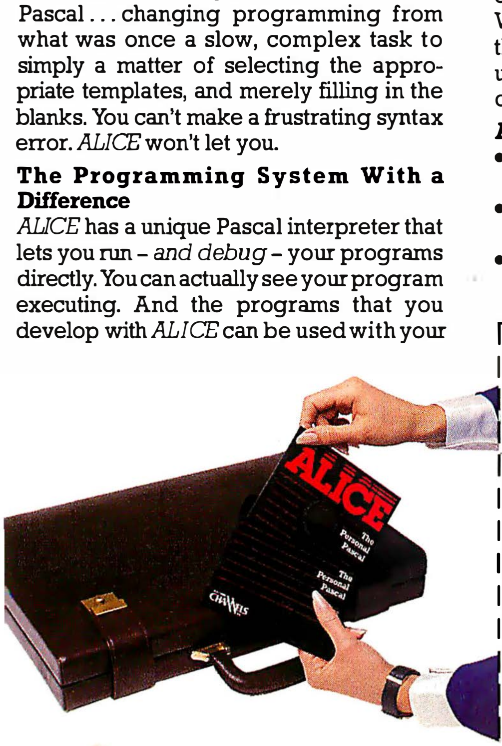
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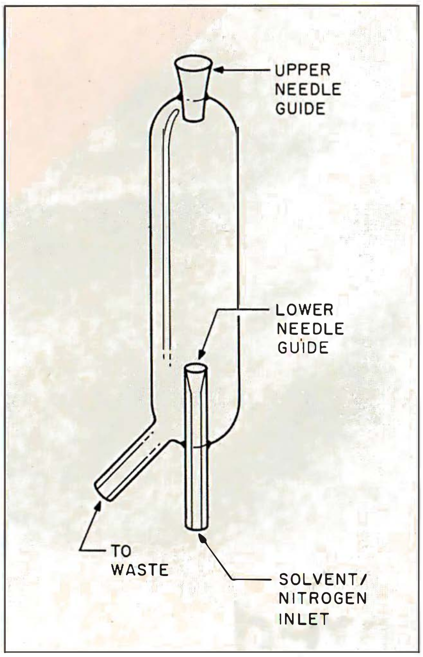


Figure 2: *Self-cleaning syringe washer.*

verter cards, and stepper-motor driver cards, are added as required by the specific application. The 44-pin bus is terminated actively on the backplane board. The front panel has LED (light-emitting diode) indicators for the system states (used during debugging), a reset button (warm start to location 0000H), and a restart button (cold start back to bootstrap PROM). A connector on the rear of the front panel allows a box with hexadecimal data/address displays, halt/run switch, and single-step switch to be attached for use during debugging. If needed, our DMA (direct memory access) card, disk-controller card, and disks can be added to create a CP/M-compatible development system.

Each managerial processor has at least one 8K-byte PROM, located at address E000H, which contains the system monitor, debugging routines similar to the CP/M DDT (dynamic debugging tool) functions, block-mode communication driver, and interrupt handlers. When the overall system is complete, there will be several managerial processors running simultaneously. It is impractical to provide a terminal for each computer, and the front-panel displays are quite limited. To debug and maintain the system, a spy feature is implemented in each manager. Periodically, the manager transmits a message from one of its serial channels describing its current activity and status. We connect the spy lines from each manager to a manual multiplexer switch connected to a single terminal. The system operator selects which manager is monitored. If this manual method proves too limited, the multiplexer and terminal can be replaced with a disk-based system that can log the activity of all the managers onto disk for postmortem analyses.

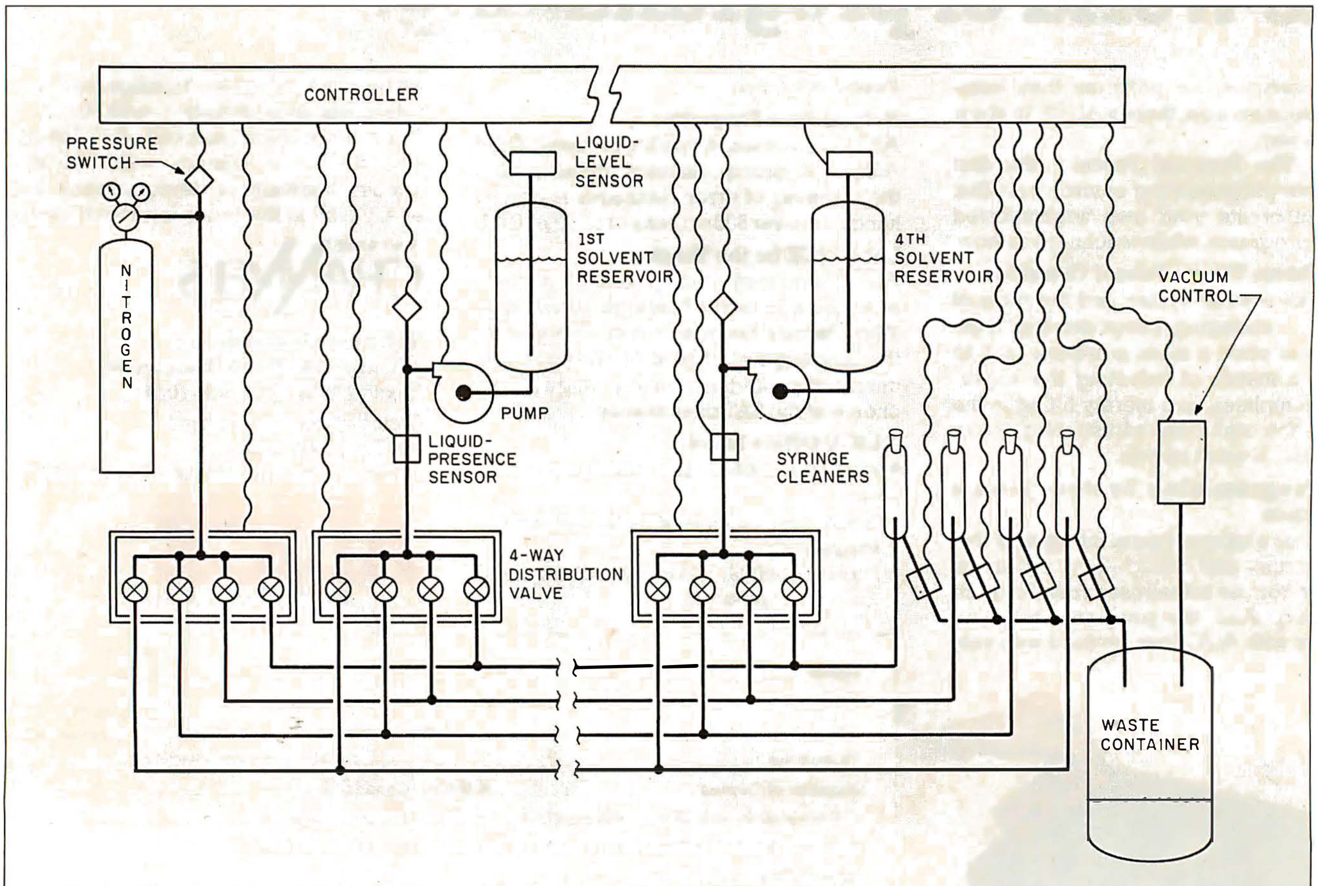


Figure 3: *Syringe-cleaner subsystem.*

Much software used by the managers will be PROM-based; only variables and special routines are downloaded after each master system reset.

ONE SUBSYSTEM IN DETAIL

Rather than give a condensed view of our entire system, it may be more illuminating to describe in some detail one subsystem, currently being built, that illustrates several techniques. First, a brief description of the robot's syringe hand is in order. The hand consists of a glass syringe whose plunger is driven by a small DC motor through rack-and-pinion gearing. A potentiometer, mechanically coupled to the drive assembly, provides position feedback. Normally, a syringe hand must be cleaned after each use. Figure 2 shows our self-cleaning syringe washer. The cleaning process involves inserting the syringe needle into the lower needle guide, drawing solvents into the syringe barrel one at a time, and then expelling them to waste, followed by pumping nitrogen in and out to dry the syringe. Sufficient solvent pressure is developed in the lower needle guide to provide efficient washing of both the syringe interior and the needle exterior. This process uses valuable robot time, since the hand must be attached to the arm for cleaning. Several other hands are available, so the robot could be doing useful work if a syringe could be cleaned while its hand is parked.

Figure 3 shows a system that alleviates the cleaning problem by allowing up to four syringe hands to be cleaned while parked. A syringe washer is placed below each parking station, and each hand is equipped with an auxiliary set of contacts that engage when the hand is parked. Parking a hand in its station initiates

The robot could be doing useful work if a syringe could be cleaned while its hand is parked.

its cleaning cycle. The controller hardware for this subsystem is identical to that in the managerial processors previously described. In figure 1, this controller is shown reporting to the robot manager. However, it may end up serving the liquid-handling manager or even becoming a full manager itself.

The solvents are stored in large containers and directed to the cleaning stations by metering pumps driven by permanent magnet stepper motors.

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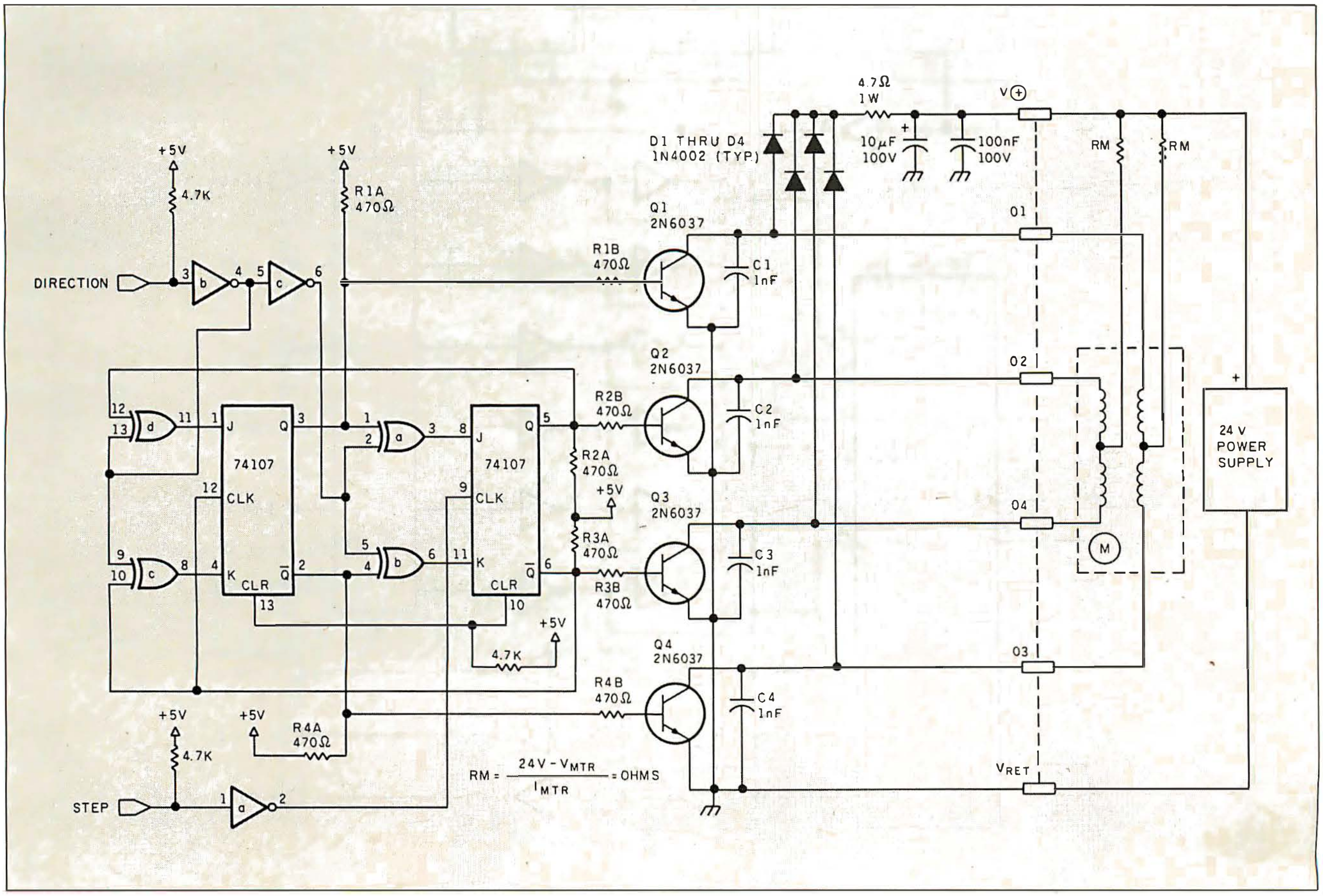


Figure 4: *Stepper-motor drive circuit.*

Solvent levels are monitored with sensors that make use of the reflectance of light passing through a glass rod.

Figure 4 shows the circuitry required for driving these four-phase motors. The direction line is left high, and the step line is driven from the buffered output of an 8253 or 8254 counter-timer controller (CTC). Our metering pumps (manufacured by Fluid Metering Inc.) deliver a fixed amount of liquid for each rotation of the motor. Solvent can be delivered at a programmable rate by using the CTC in the rate-generator mode. If a fixed amount of solvent is to be delivered, the rate-generator CTC can be gated with the complemented output from a second CTC channel that is used in the interrupt on terminal-count mode. Figure 5 shows one of the CTC circuits on our real-time clock card. Easy selection of true or complemented signals improves the flexibility of this card.

System reliability is improved by several sensors mounted near the pump. Solvent levels in the reservoirs are monitored using sensors that make use of the internal reflectance of light passing through a glass or quartz rod whose tip is cut to a 90-degree taper. According to Snell's law, when the tip is surrounded by a low-refractive-index medium such as air, light passing through the rod will be totally reflected. When the refrac-

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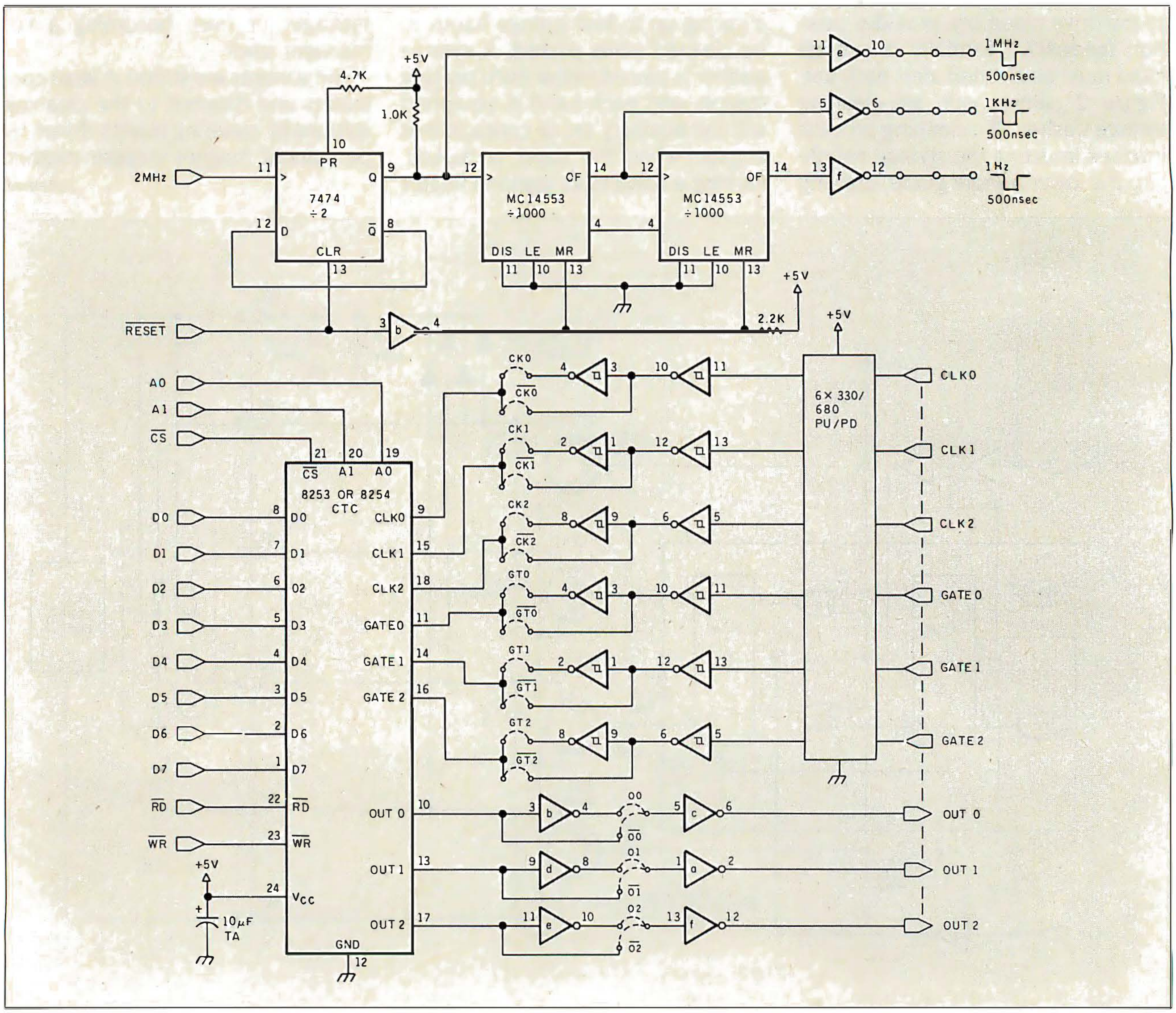


Figure 5: *Real-time clock (CTC) circuit.*

tive index of the surrounding medium is higher, such as with a liquid, a portion of the light passes from the rod into the liquid (figure 6). If a photodetector is placed at the flat end of the rod, its output will decrease when the conical tip of the rod is immersed in a liquid. A simple comparator circuit (figure 7) converts this change into a computer-readable signal. A version of this sensor, the LQD Liqua Sense Liquid Level Sensor, is commercially available. The simple design shown here must be shielded from external light; however, a more sophisticated synchronous detection scheme (such as the Liquid Level Quartz Sensor from NSG Precision Cells) can virtually eliminate this problem.

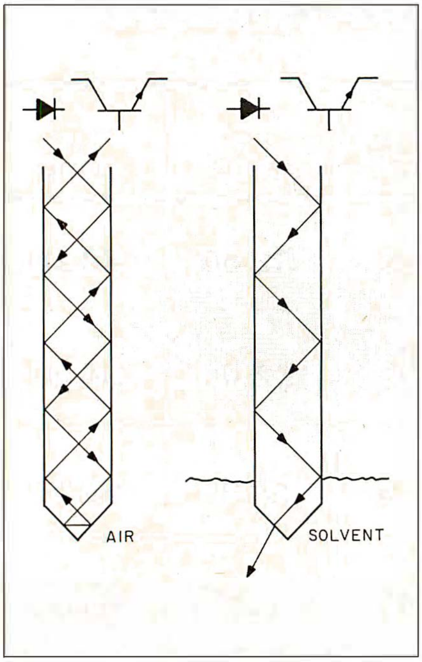


Figure 6: *Reflective liquid-level sensor.*

To ensure that the pump retains its prime, a flow-through sensor is mounted on the pump output to detect the presence of the liquid in the Teflon tubing leading to the distribution valve. This device uses an LED and a phototransistor on opposite sides of the translucent Teflon tubing to detect the presence of a liquid. Again, a comparator circuit (figure 7) provides a TTL (transistor-transistor logic) level signal. To shield this sensor from ambient light, the LED and phototransistor are mounted in an opaque plastic block (figure 8), and the entire circuit is housed in a small black plastic Pomona Box. We know of no commercial versions of this sensor that are as small as the one described, but models that work with larger tubing are readily available (the Optical Liquid Detector, the S19 Sight Glass Scanner, and the Bantammeter Optical Sensor).

A small bellows-type pressure sensor on the outlet of the pump is used to detect an overpressure condition due to a fully closed distribution valve or a clogged tube. The TTL outputs from these sensors are brought into the controller through a 16-bit buffered parallel I/O card. Figure 9 shows the input section of this circuit.

The effluent from each pump is brought to a four-way distribution valve whose exit ports lead to the individual washing stations. These distribution valves are typical of the miniature solenoid valves used in this project, which feature small internal volume (30 to 60 microliters), high-speed operation (8 milliseconds), low power drain (12 volts DC, 210 milliamperes), and all Teflon wetted parts (Series 1, 2, and 18 Miniature Teflon Solenoid Valves). Since the current required to drive these valves is greater than that provided by standard open-collector TTL drivers, additional buffering is provided as shown in figure 10. The diodes protect the switching transistor from the voltage spikes generated when the solenoid valve is

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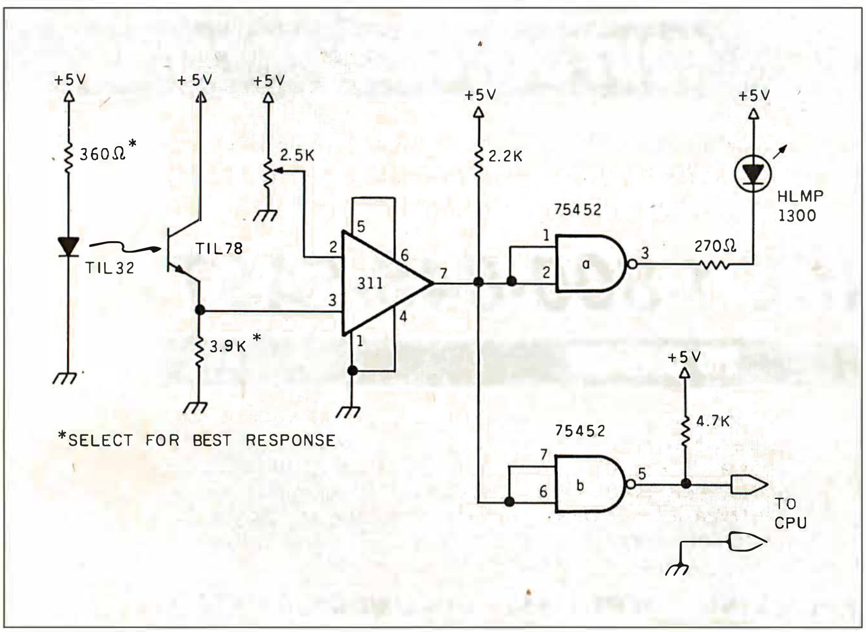


Figure 7: *Optical fluid detector circuit.*

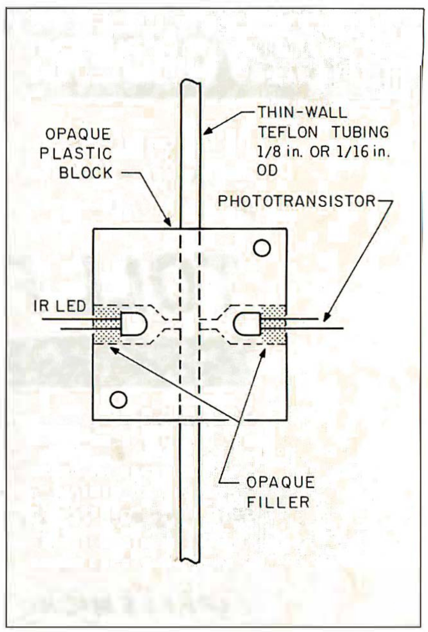


Figure 8: *Liquid-presence detector.*

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Equivalent Program Segments

```
;--------PROMAL--------
REPEAT
   PROMPT_AT 5,24, "Add/Chg/Quit?
   IF Reply = 'A'
      ADD item
      New_Items = New_Items + 1
   ELSE IF Reply = 'C'
      CHANGEItem
UNTIL Reply = 'Q'
```

```
11910REM -----BASIC---------
11920CL = 5:LN = 24:PR$ = "Add/Chg/Quit?"
11925GOSUB 9490:REM GET REPLY
11930IF RP$<>"A" THEN 11950
11940 I9 = IT:GOSUB 10100:REM ADD
11945 NI = NI + 1:GOTO 11920
11950 IF RP$<>"C" THEN 11970
11960 I9 = IT:GOSUB 6050:REM CHG
11970 IF RP$<>"O" THEN 11920
```

PROMAL is readable and understandable. You see the logic from the structure. And PROMAL lets you call procedures by name – so no more GOSUBs. But there's more.

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- Strings & pointers
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- Bit-operators, shifts, type casts
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- Prior command recall
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- Memory MAP, SET, and display commands

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- Function key controlled
- Line insert, delete, search
- String search and replace
- Block copy, move, delete & file read/write operations
- Auto indent, undent support

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- Re-directable I/O (STDIN & STDOUT)
- Formatted numeric output
- Decimal & Hexadecimal I/O
- Block fill/move/read/write
- Cursor control & line editing
- Data type conversion
- Random number function
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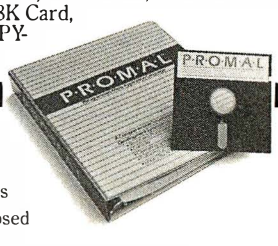
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turned off. The capacitor connected from collector to emitter on the switching transistor slows its switching speed, preventing secondary breakdown from the turn-off transient of the inductive load. Drive for these current boosters is derived from a 16-bit buffered parallel I/O card. Figure 11 shows the output section of this circuit. The DP8311 octal peripheral driver is used as a medium-power (100 mA per line) open-collector inverting buffer. The SIP resistor pack on the outputs is optional and is not used when the power booster circuit is used.

The DC motor on the syringe hand that drives the syringe plunger is controlled by the circuitry shown in figure 12. The location of the plunger corresponding to the empty and full positions is discerned by a pair of comparators that monitor the voltage across the position feedback potentiometer in the hand. In this cleaning operation, we monitor only the open and closed positions of the plunger. When given an UP signal from the controller, the plunger is allowed to slew to the top position: a $\overline{\text{DN}}$ signal slews the plunger to the bottom. The controller can determine the position of the plunger by monitoring the $\overline{\text{TOP}}$ and $\overline{\text{BOTTOM}}$ signals. A third input signal, $\overline{\text{HAND PRESENT}}$, detects

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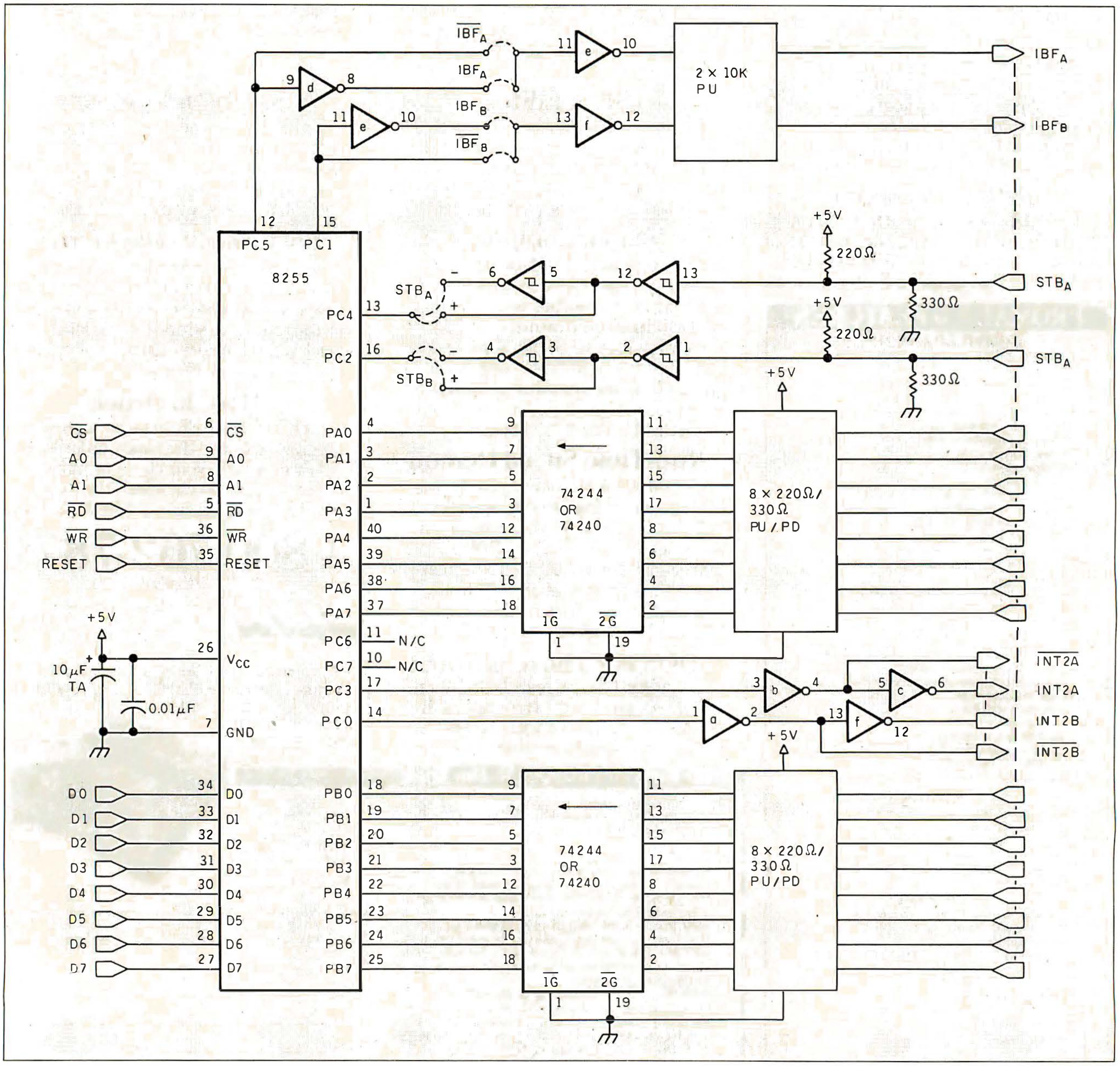


Figure 9: *16-bit buffered parallel input circuit.*

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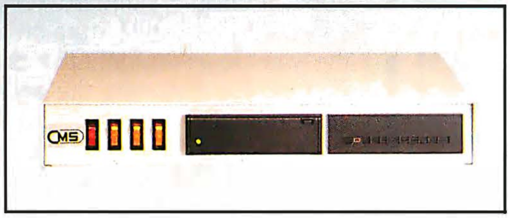
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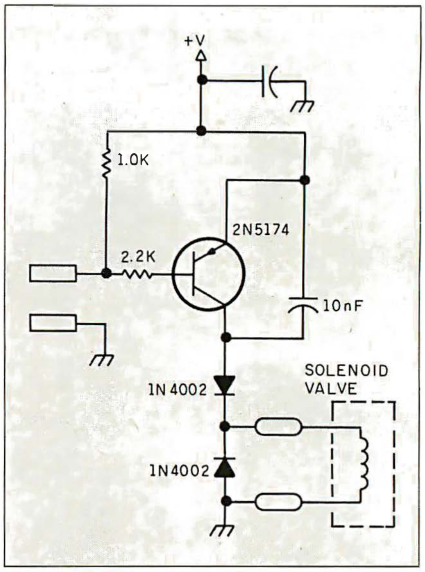


Figure 10: *Valve-driver power booster circuit.*

when the hand has been placed in its parking station. One subtle feature is the internal interlock signal. This signal is generated by a magnetically actuated reed switch on the parking station. The magnet is attached to the robot arm. The purpose of this circuit is to prevent power from the auxiliary contacts from being applied to the hand when it is still attached to, and powered by, the robot arm. To activate the syringe cleaner drive, the robot arm must physically back away from the hand.

The final device controlled in this application is a standard 120 V AC solenoid valve used to turn on and off the water to an aspirator that provides vacuum for removing the waste solvent. This valve is controlled by an optically coupled solid-state relay driven directly from a DP8311 output. Liquid-presence sensors on each waste line are used to help ensure that the washing operation actually occurred.

Having described the hardware, let us examine some of the software requirements. Since this is a subsystem, it must be able to communicate with a higher-level computer. The communication is done serially over an RS-232C link in a block protocol, with CRC-16 error checking and automatic

(continued)

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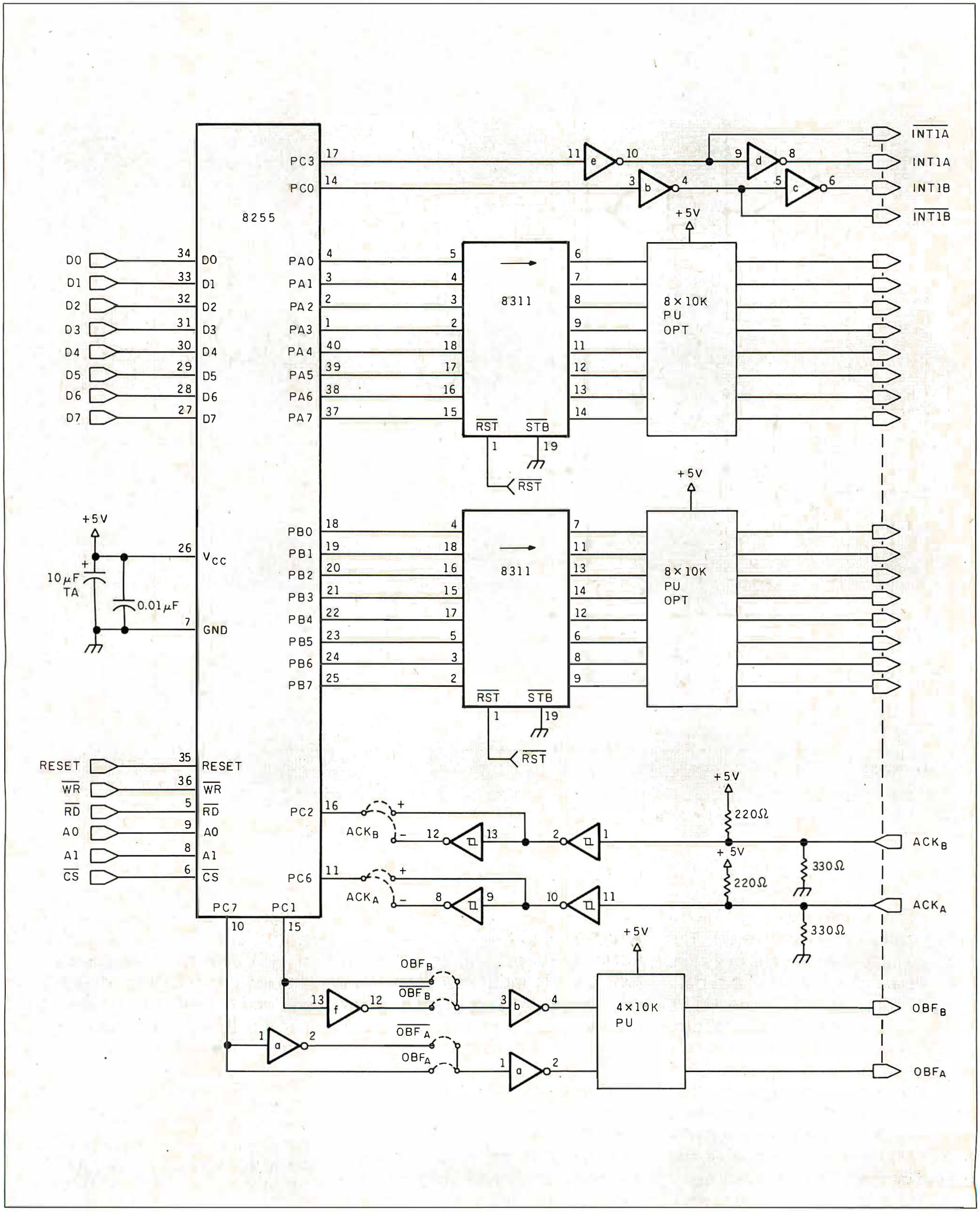


Figure 11: *16-bit buffered parallel output circuit.*

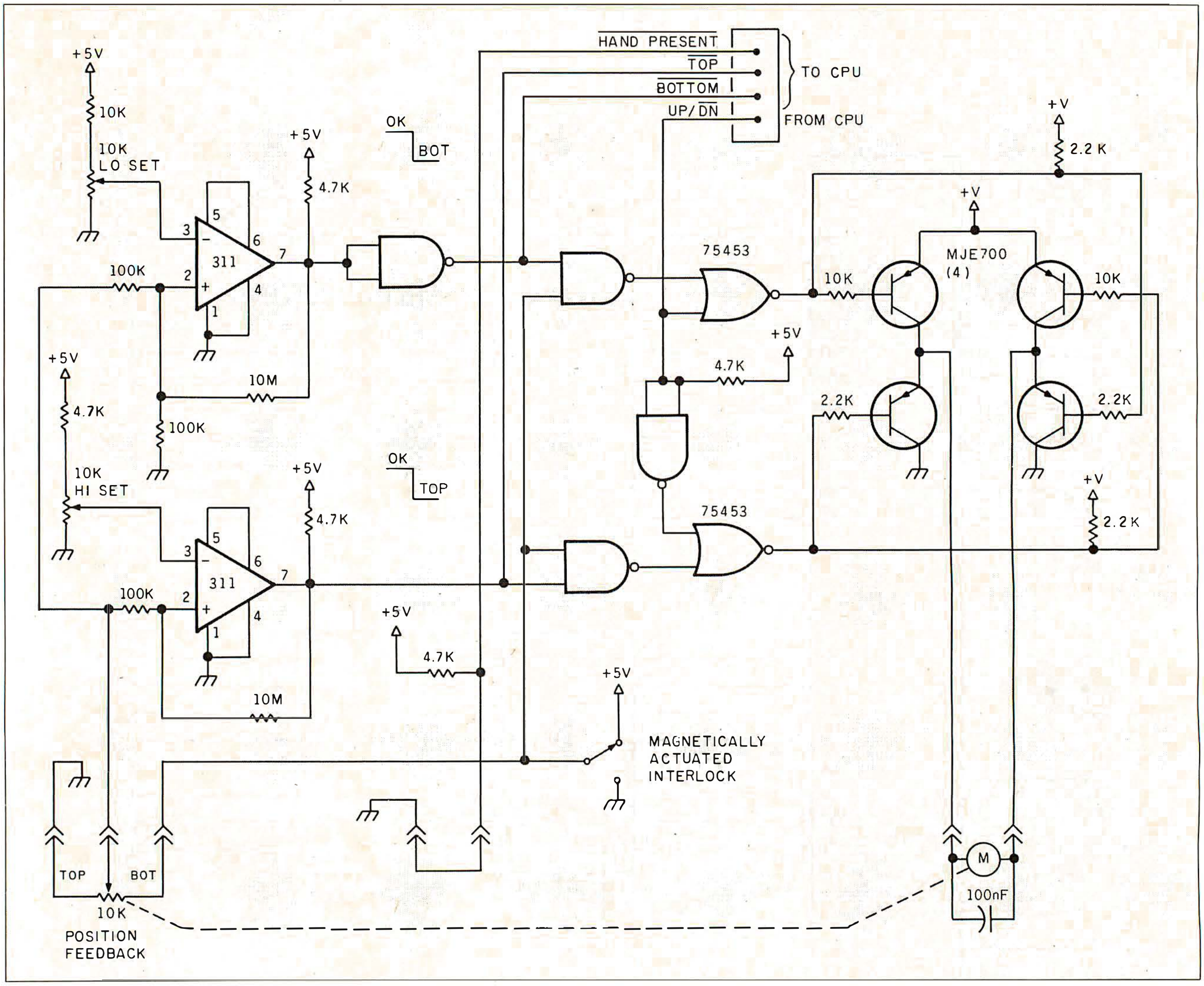


Figure 12: *Parked syringe hand drive circuit.*

retransmission of bad blocks. The most common request from the superior processor will be "Which syringe hand is clean and ready?" The subsystem must answer this question, but if no hand is available, it should give an estimate of when one will be ready. This allows the calling processor to set a countdown timer that avoids redundant requests for a clean hand when none is available. Another interaction with the calling processor is downloading a special cleaning procedure to be used in place of the default method. The local processor should be able to handle routine error conditions such as a pump losing its prime, but it will have to report fatal errors, like being out of solvent, to the superior processor.

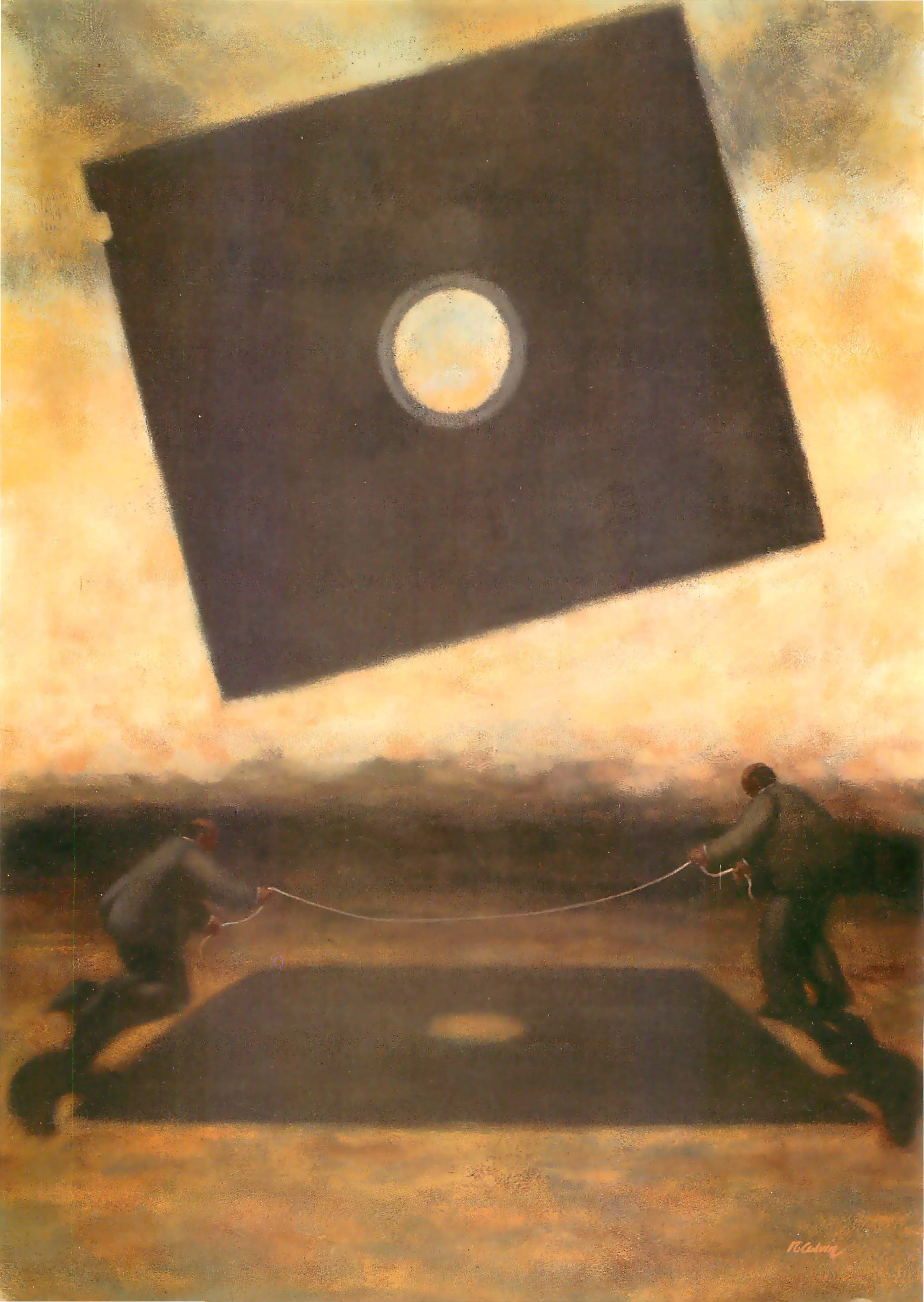
A Look into the Future

In the evolution of this project, many problems like the syringe cleaner will continue to be encountered. Some can be sidestepped, others ignored, but many will require solutions. The software will be formidable, but hopefully the user interface will hide most of this so that the system will not intimidate its users. Even when complete in its present design, our system will require input from a highly trained chemist to produce useful results. This may not always be so. Rapid progress is being made in the parallel field of computer-aided synthetic design. The future marriage of an automated synthesis system such as ours and a synthesis-design computer will result in a quantum leap in organic chemistry: the ability to design, carry out, and optimize the production of a material under the guidance of a computer. ■

ACKNOWLEDGMENTS

We would like to note especially the hard work of Doug Lantrip, Mike Trueblood, and Roger Frisbee, without whom most of this system would still be on paper. Financial support by Hoffmann-LaRoche Inc., The Dow Chemical Co., Eli Lilly and Co., and the National Science Foundation (CHE-8406115) is gratefully acknowledged.





Reviews

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WE BEGIN OUR SYSTEM REVIEWS this month with a look at Canon's A-200 computer. The unit is based on an 8086 microprocessor running at 4.77 MHz and comes standard with 256K bytes of RAM, 16K bytes of ROM, and a 4K-byte permanent diagnostics routine in ROM. Other memory features are 4K bytes of video RAM if you choose a monochrome monitor and 16K bytes of video RAM if you get the unit with the color monitor. Reviewer Peter Callamaras was struck by what seems to be a good amount of room in the system housing for both expansion boards and a possible hard disk. It comes with two half-height 360K-byte 5¼-inch floppy-disk drives.

The Color Fox from Scottsdale Systems started its existence as the Sanyo MBC-555 computer. From there, however, some substantial modifications were made. The result, according to reviewer John Unger, is something that is generally more IBM PC-compatible than the earlier Sanyo but is still less so than such offerings as the Compaq or the Zenith Z-150. Mr. Unger makes the point that most of the enhancements to the Sanyo to create the Color Fox are hardware.

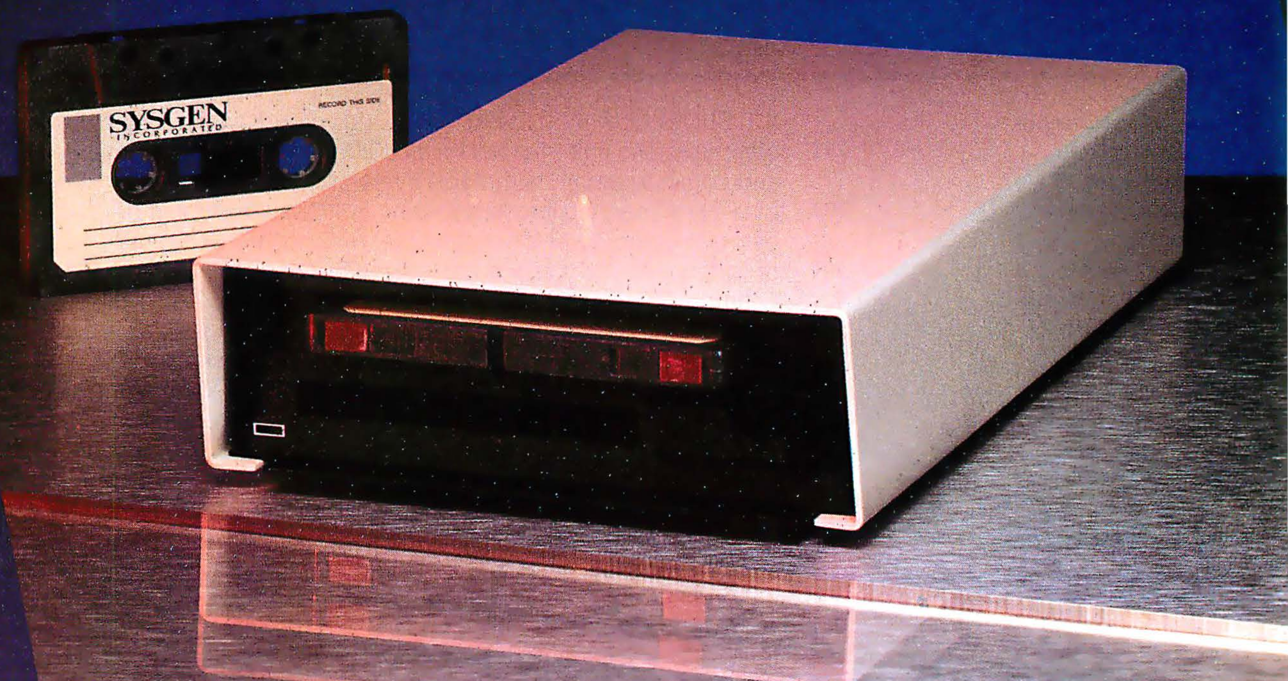
David D. Clark, in his review of Ecosoft's Eco-C88 C compiler for Z80 CP/M systems, notes that this is an update of a product that was less than sterling in its earlier incarnation. Now, however, he feels that the changes made to the compiler not only make it worth another look but have improved it to the point where he can give it a good recommendation.

Next, Douglas E. Hall gives us the benefit of his experiences with The Sider hard-disk drive for the Apple II+ and IIe. The 10-megabyte external hard disk not only was affordable but was offered with a 15-day free trial that was just too much of a good thing to pass up. How well did it live up to its advanced billing? As with everything, reports Mr. Hall, there are pluses and minuses.

Architectural differences between the IBM PC and the PC AT have created a new load of enhancement products that are designed to do for the latter what has long been available to owners of the former. A case in point is the subject of a review by TJ Byers: the Advantage! multifunction board for the AT from AST Research. You can load the Advantage! with almost 10 times the RAM of another AST product, the SixPakPlus, which is designed for the IBM PC. What you could wind up with is an extra 3 megabytes of memory in a single expansion slot.

Reviewer Steve King takes a hard look at an integrated software package called Enable from The Software Group. Here we have a $695 package claimed in its initial version to be a word processor, database manager, spreadsheet, and data-communications program. There are a lot of promising aspects to the package, says Mr. King, and indeed the producer has refined it in a subsequent version. However, you'll want to read this review for its thoughtful and well-documented analysis of a package undergoing evolution.

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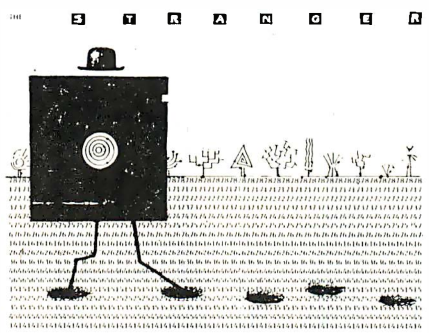
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We seem to have an endless supply of products to review. This month, I thought I'd give you a little preview of what's in store.

Consider Pocket APL from Scientific Time Sharing Corp. (STSC). APL's a language that has long been popular as a teaching tool but never left school with the graduating students. One of the reasons why it suffered in comparison with other languages was the fact that you needed relatively expensive and specialized hardware to implement it. For example, using APL used to mean that you had to have at least an 8087 numeric coprocessor and a special-character ROM (read-only memory). Now, with Pocket APL, you can go about your business with nothing more specialized than an IBM Personal Computer with 128K bytes of RAM (random-access read/write memory). Judging from the review now in process, this is a complete, though compact, implementation of APL with extended system and file functions, on-line help facilities, and sample workspaces on one disk.

On the other hand, Pocket APL looks like a learner's tool in that it emphasizes user-friendliness, and it would probably be of more use to you if your applications are going to be small. Further, it has at least one serious disadvantage in that it limits its workspace to 64K bytes, regardless of the size of the memory on your machine. You can get versions of APL from STSC that are more full-featured (greater memory utilization, full-screen editing, graphics, etc.). However, these implementations are proportionally more expensive than Pocket APL and are the ones you'll want to keep in mind if your learning experience on the compact version piques your interest about going further. The review reveals that the language has some surprising capabilities.

Other reviews we've got cooking for the months ahead include one on Ericsson's laptop portable computer. The company announced several months ago that it would no longer be selling this attractive, plasma-screen unit in the United States—which turned out to be both true and not true. Ericsson will no longer sell the computer line through retail outlets or through normal computer distributors. The computers will be available directly from the company, Ericsson tells us. (Ericsson telecommunications equipment is still being actively sold.) BYTE's readers throughout Europe will still be able to purchase the Ericsson laptop through normal channels. Whether or not the computer is worth the extra trouble it will take to own one in the U.S. is a good question. We're hoping this review will provide enough information to make it answerable.

An interesting example of resurgence is the Ace 2000 series from Franklin. The reorganized company claims that the 65SC02 processor used in its Apple II-compatible machine is functionally identical to the 65C02 used in both the IIe and IIc and is therefore a true work-alike for the IIe, II+, and IIc. Its "Franklin DOS" operating system is claimed compatible with both Apple DOS 3.3 and Apple ProDOS as well as being faster on disk-access functions. Further, it comes with its own version of BASIC in ROM. Franklin is now producing the Ace 2000 in models equipped with two, one, or no disk drives, and the monitor is an extra-cost option no matter which model you buy. As to price, the no-drive system was introduced at $699, with the one- and two-drive models costing $849 and $999, respectively. Standard features include 128K bytes of RAM, capability for 80-column display and double high-resolution graphics, and a parallel printer card. With a 67-watt power supply, it has more than enough power to support a hard disk.

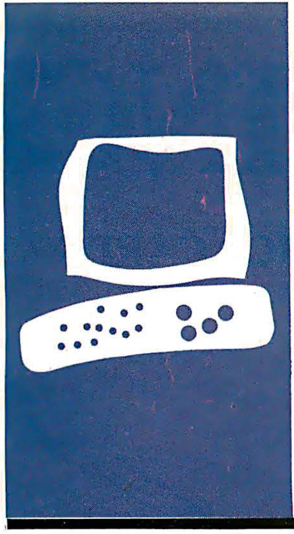
All in all, you seem to get quite a bit for your money. We expect to have more to report when the review finally appears in print.

We're also looking at a review of an interesting data-storage and -retrieval device for the Commodore 64. Called the Quick Data Drive, from Entrepo Inc., it reads and writes data on miniature wafer-tape cassettes. The company claims its unit is not only 20 times faster than a cassette drive but is also faster at loading programs than the Commodore disk drive. Tape-loop lengths vary from a 56K-byte capacity of 20 feet up to a 62-foot model that will hold more than 170K bytes of data. You can designate up to 255 files on one wafer. A number of other intriguing aspects to this drive could make it worth investigating if you have a Commodore 64, and there are a number of things you're going to have to live with that may or may not present problems in your particular applications.

Other review topics for the near future will be: C compilers, expert-system development tools, high-speed modems, text- and data-compression products for storage and communications, more full systems, and peripherals from hard disks to printers.

—Glenn Hartwig
Technical Editor, Reviews

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Canon's A-200

An IBM PC-compatible with room to grow

BY PETER V. CALLAMARAS

The Canon A-200 computer system is a three-piece unit consisting of a video display, a keyboard, and the computer itself. The computer is built around an 8086 microprocessor running at 4.77 MHz.

The A-200 comes standard with 256K bytes of RAM (random-access read/write memory) and 16K bytes of ROM (read-only memory). A 4K-byte permanent diagnostics routine executes when you turn the power on. With the monochrome monitor, you get 4K bytes of video RAM; with the color monitor, you get 16K bytes. You also get an RS-232C port, a Centronics parallel port, and a place to plug in an 8087 numeric data processor.

Five IBM PC-compatible slots are built into the A-200, but you can use only four, since one is for the video-interface card. Two of the slots are on a 16-bit data bus (one is used by the video-display adapter); the other three are 8-bit. One nice feature is the ability to add 256K bytes of RAM (from Canon) without using any of the remaining four expansion slots. You can go to a 512K-byte system and have four slots left for expanding.

The system reviewed had two half-height 360K-byte 5¼-inch floppy-disk drives. I saw no mention of a hard disk from Canon, but the system should accept any third-party IBM-compatible drive with no problem. |*Editor's note: Canon now has A-200 systems with a 10-megabyte hard-disk drive and a 360K-byte floppy-disk drive.*|

Internally, the drives take up most of the front right-hand side, the power supply and fan are behind the drives, and the expansion slots are on the left. There appears to be plenty of room for the necessary working space when you add boards. The ROM chips are readily accessible, just behind the left-hand disk drive, so any updates would be simple to make. Reading the names on the various components inside makes it evident Canon has gone to some pretty good subvendors for parts, with drive components from Sankyo and a Kyocera power supply/fan case (used in the Radio Shack Model 100 and the NEC PC-8401A laptop portable). One concern I have is how well the fan would do in cooling added components, since there doesn't appear to be any venting to draw air across the expansion-slot area. With a "full house" system, any potential for overheating needs to be considered.

THE KEYBOARD

The keyboard is a standard IBM PC-style unit with 10 function keys on the left side, a QWERTY keyboard in the center, and a numeric keypad on the right for a total of 83 keys. Unfortunately, Canon duplicated the IBM keyboard without any improvements—not even status lights on the Caps Lock key or a decent-size Return key (see photo 1). While the keyboard appears plug-compatible with the IBM PC (so you could use a third-party or IBM keyboard if desired), Canon could have made a lot of friends by improving the keyboard. The keys have a very light yet comfortable feel but offer no resistance or feedback when pressed. You can end up with a string of the same letters if you aren't light-fingered. I liked the keyboard, despite its shortcomings, because of the quiet keys.

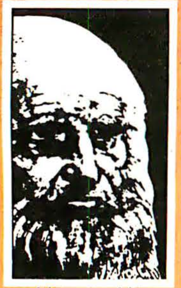
THE DISPLAY

For the video display, you have a choice of color or monochrome (P-39 green) units mounted in a swivel/tilt housing that works nicely. I could just set it and forget it. The display is connected with a nine-pin cable running between the rear of the computer and the monitor.

The monochrome unit gives you the standard 80-character by 25-line display, but it's with the color monitor that the A-200 really shines. The color monitor is rated at 40/80 characters by 25 lines with a total of 16 colors available. You get 640 by 200 pixels in black-and-white mode and 320 by 200

(continued)

Peter V. Callamaras is a captain in the U.S. Air Force. His interests are computers, model railroading, photography, reading, and physical conditioning. He can be contacted at POB 408, Scott Air Force Base, IL 62225.



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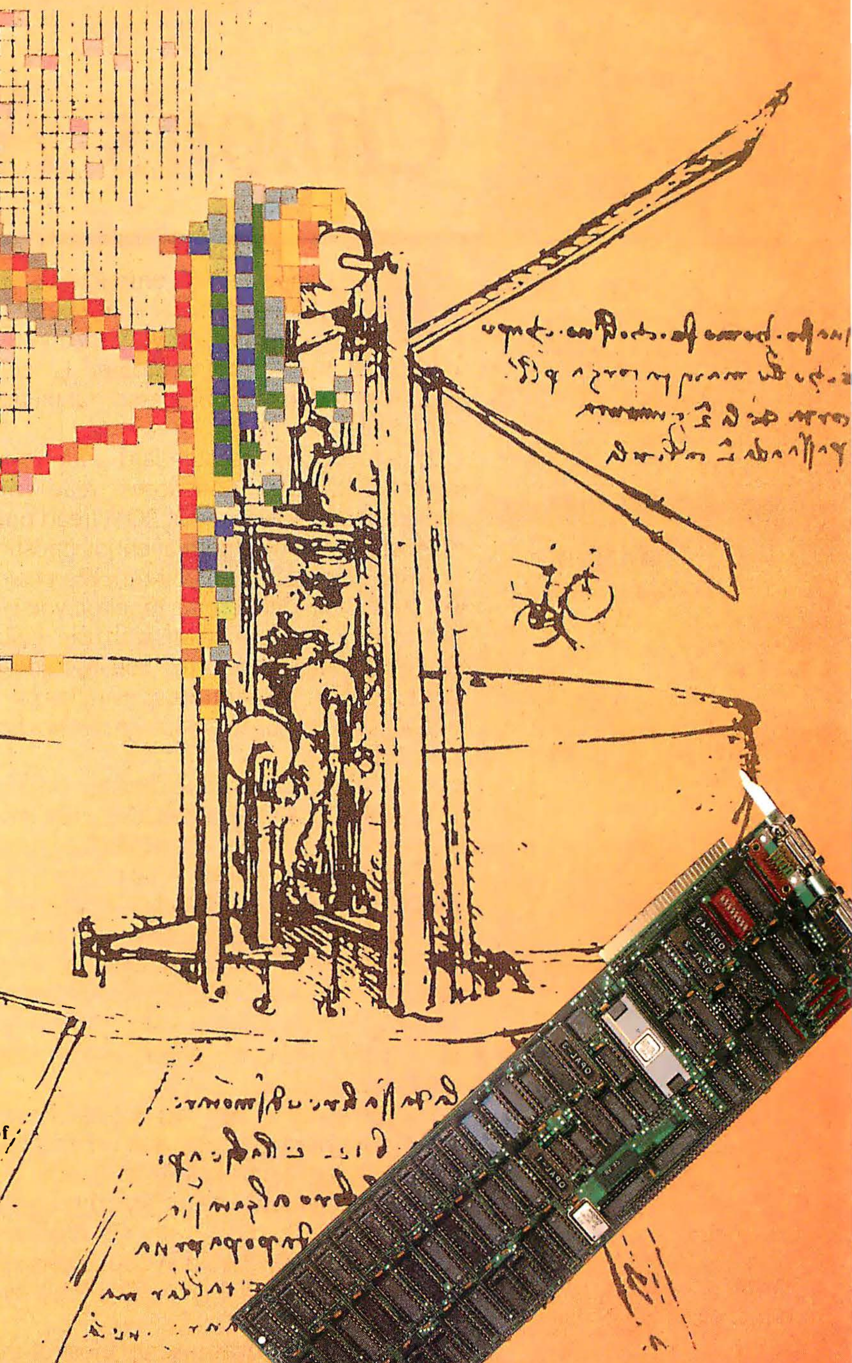
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- **Use with standard IBM color TTL RGB monitors.**
- **Supports analog RGB monitors on the basic card.**
  (You get ultra high resolution color that is normally only available on mini and mainframe computers.)
- **Standard resolution of 640 by 400, 16 colors with 128K of video ram on the Silver Card.**
- **Maximum resolution of 1024 by 1024, 16 colors with 512K of video ram on the Gold Card.**
- **Expansion connector:**
  Allows upgrades which extend and enhance the features of the basic card—no more obsolete hardware. Planned extensions include:
  - *256 colors (8 bits/pixel) displayable from a pallete of 262,144 colors.*
  - *512 colors (9 bits/pixel) displayable from a pallete of 16,777,216 colors.*
- **Display characteristics are fully programmable**
  - *Interlaced mode allows use of low cost monitors.*
  - *Non-interlaced mode for flicker-free display*
  - *Display size up to 1024 by 1024 (40MHz bandwidth.)*
- **Flash hardware enable/disable on 4 colors (Layers) allows any of 4 specified layers to be temporarily "disabled" i.e., erased, then later can be "enabled", i.e., put back on the screen without being redrawn.** *This greatly increases speed of use.*
- **Light pen input port. (Permits a light pen to be used as a pointing or pick device)**
- **Hardware pan and zoom support. (Allows smooth panning, and zoom up to 16 times magnification)**
- **Compatible with existing software including AutoCAD, p-cad, VERSACAD, MasterCAD, etc.**
- **Software support. Planned software includes Tektronix emulation, Graphics support library.**



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AT A GLANCE

Name
Canon A-200

Company
Canon U.S.A. Inc.
One Canon Plaza
Lake Success, NY 11042
(516) 488-6700

Components
Processor: 8086, 4.77 MHz
Memory: 256K bytes
Mass storage: Two 5¼-inch double-sided double-density floppy-disk drives, 360K bytes each
Display: 80 columns by 25 lines, 640 by 200 pixels (black-and-white); 40/80 by 25, 320 by 200 pixels (color)
Keyboard: 83 keys, including 10 function keys and numeric pad; IBM PC layout
I/O interface: Centronics port, RS-232C port, five expansion slots (two 16-bit, three 8-bit)

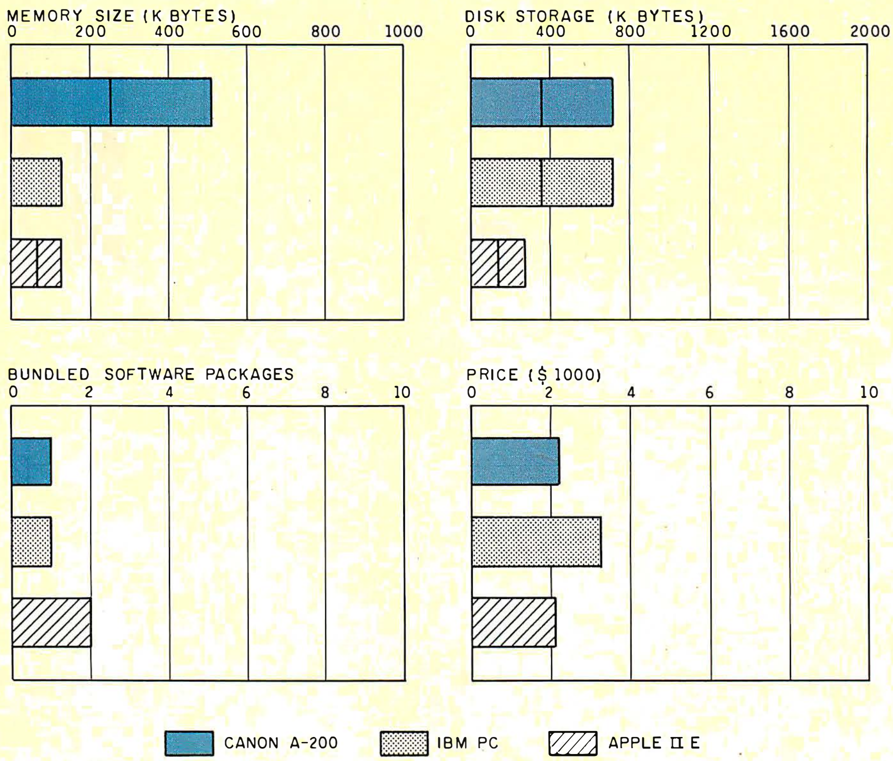
Software
MS-DOS 2.11, GW-BASIC, diagnostics

Options
256K-byte RAM module

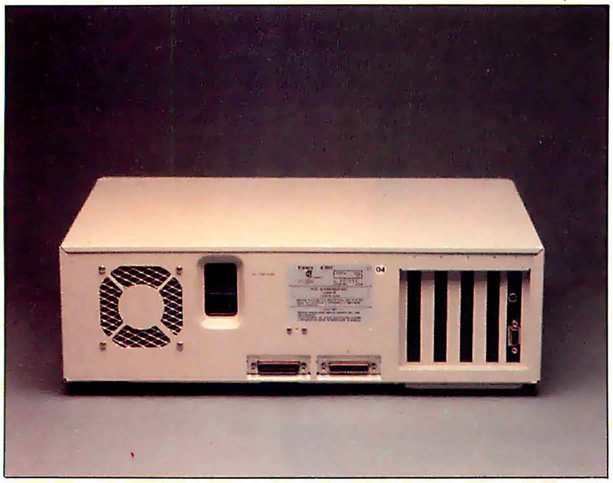
Documentation
Manuals for software and machine

Price
A-200 M2 (256K memory, two floppy-disk drives, monochrome monitor) $2195
A-200 C2 (256K memory, two floppy-disk drives, color monitor) $2695

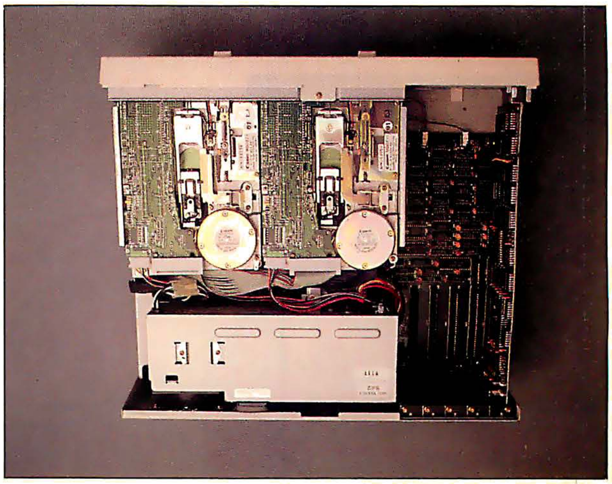




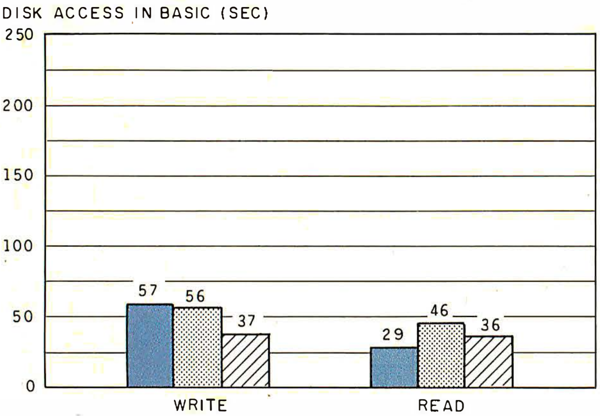
The Memory Size graph shows the standard and optional memory available for the three computers under comparison. The Disk Storage graph shows the highest capacity of one and two floppy-disk drives for each system. The Bundled Software Packages graph shows the number of software packages included with each system. The Price graph shows the list price of each system with two high-capacity floppy-disk drives, a monochrome monitor, a printer port and a serial port, 256K bytes of memory (64K bytes for 8-bit systems), and the standard operating system and BASIC interpreter for each system.

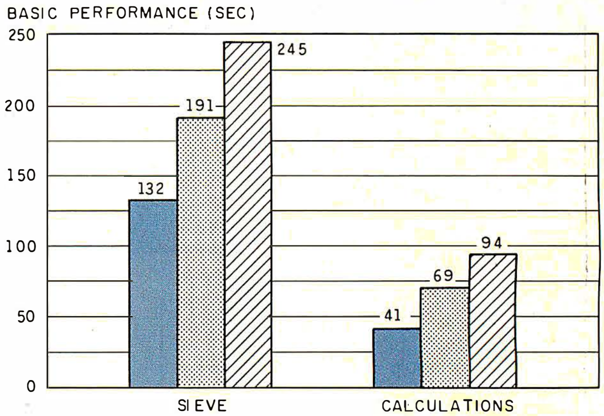


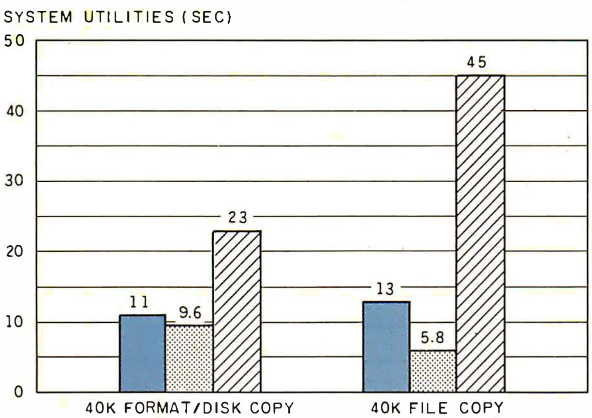
The rear view of the Canon A-200 shows (from left to right) the blower fan, power cord receptacles, serial port and parallel port, and expansion slots.

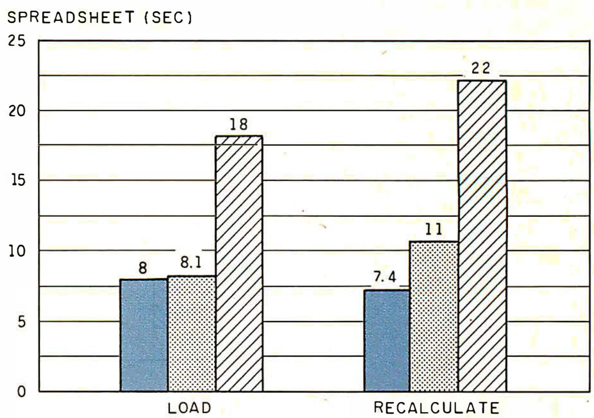


Inside the A-200. At the lower right are the expansion slots; the power supply is at the lower left. At the upper left are the floppy-disk drives.









CANON A-200 IBM PC APPLE IIE

The graph for Disk Access in BASIC shows how long it takes to write a 64K-byte sequential text file to a blank floppy disk and how long it takes to read this file. (For the program listings see June 1984 BYTE, page 327, and October 1984, page 33.) In the BASIC Performance graph, the Sieve results show how long it takes to run one iteration of the Sieve of Eratosthenes prime-number benchmark. In the same graph, the Calculations column shows how long it takes to do 10,000 multiplication and 10,000 division operations using single-precision numbers. The System Utilities graph shows how long it takes to format and copy a disk (adjusted for 40K bytes of disk data) and to transfer a 40K-byte file using the system utilities. The Spreadsheet graph shows how long the computers take to load and recalculate a 25- by 25-cell Microsoft Multiplan spreadsheet where each cell equals 1.001 times the cell to its left. The tests for the Canon A-200 C2 computer used MS-DOS 2.11 and GW-BASIC. The tests for the Apple IIe were done with ProDOS (except for the spreadsheet, which was done with DOS 3.3). The IBM Personal Computer was tested with PC-DOS 2.0 and BASICA.



Photo 1: *Keyboard of the Canon A-200 computer. It is identical to the IBM PC keyboard.*

pixels in four-color mode. This is a crisp, comfortable monitor to view, and I had no problem with text and graphics. Since you can mount the monitor on top of the basic computer system, the whole unit takes up only 17¾ by 15⅛ inches.

SOFTWARE AND MANUALS

Other items that come with the A-200 are MS-DOS 2.11, GW-BASIC 2.02, manuals for each, a 72-page manual for the computer, a self-prompting diagnostics disk, and a short pamphlet about the monitor. The manuals for DOS and BASIC (about 167 and 335 pages, respectively) are mainly for reference; you will have to supplement them with outside material if you don't know how to program in BASIC or want to work extensively with DOS. They are definitely not novice-level "how-to" manuals. The system manual is fairly well done and leads you through setup and operation. I did have a problem when it came to booting the system up the first time due to the manual's organization. I followed the manual in a serial fashion. I inserted a disk and then waited for it to boot; it wasn't until I turned to the next page that I read you're supposed to push in the head-lock button. The head-lock button actually has a dual function: to pop a disk out and to raise and lower the head. Warnings placed on a following page are seldom read in time, so they should be on the same page as the actions they relate to. Other than that slight anomaly, the manuals do their job in helping you get the system up and running.

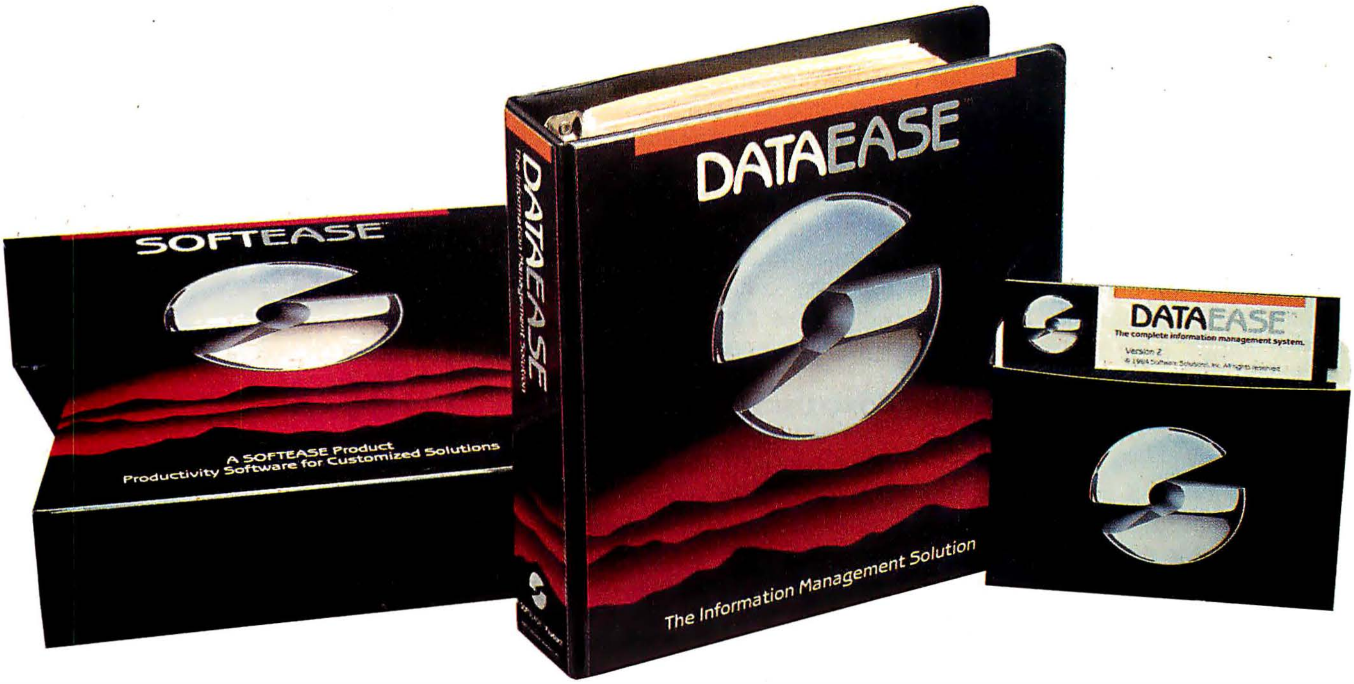
IBM COMPATIBILITY

The main question most users will have is just how IBM PC-compatible the system is. Happily, it is very PC-compatible. As mentioned earlier, the system comes with MS-DOS and GW-BASIC, so no problems there. The system also booted with PC-DOS 2.1 and 3.0, and I did not notice any problems. I also ran compatibility tests with WordStar, Lotus 1-2-3, and Flight Simulator, all without problems. Other programs (including FlashCalc, Dollars and Sense, and Statpro) also ran without any noticeable problems. Canon claims to have tested 400-plus programs, and the only programs reported to have had any problems were some games, but Canon mentions no names.

CONCLUSION

Overall, I found the A-200 with color monitor to be a very attractive system in terms of both looks and capability. I enjoyed using the system, and the color monitor is absolutely outstanding. It has been said that the Japanese incursion into the U.S. computer market follows their classic motto, "Take a product and then make it a little better and a little less expensive." While the Canon A-200 is not a quantum leap over the IBM PC, it is a less-expensive alternative in a capable package. ■

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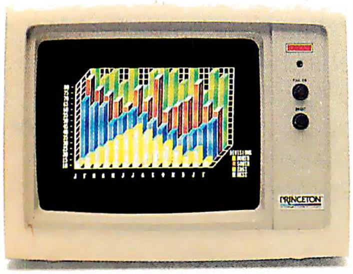
Switzerland, France
Softsource, S&A 1222 Vesenaz, Switzerland; 022-3518-55

United Kingdom
Sapphire Systems, Essex; 01-554-0582

West Germany, Austria
M&T Software Verlag, Munich; 089-4613-0

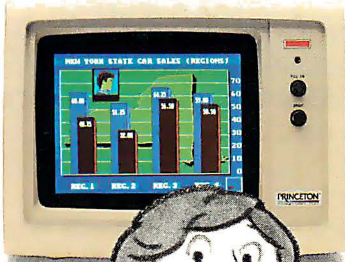
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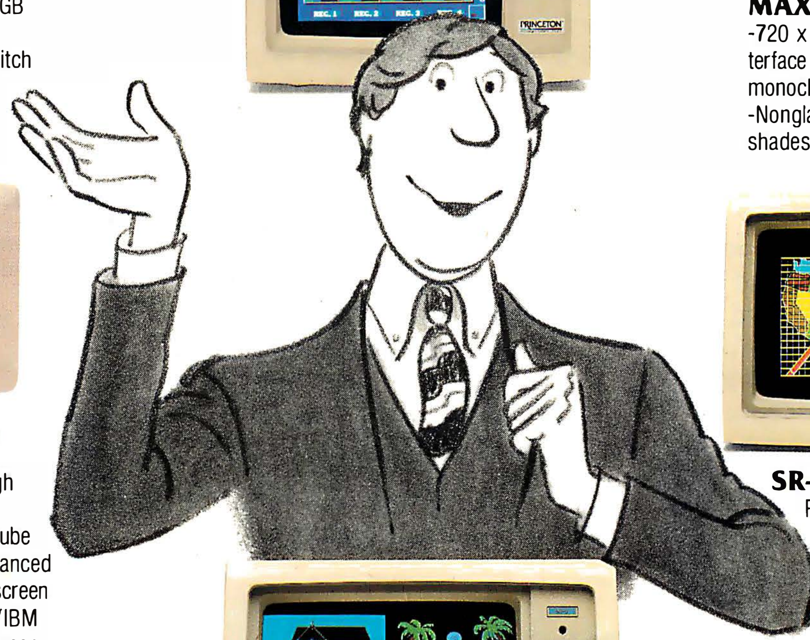
HX-12. High resolution RGB monitor -640 x 200 lines noninterlaced -.31 mm dot pitch tube-Nonglare screen -**$695**

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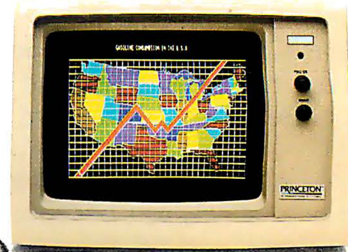


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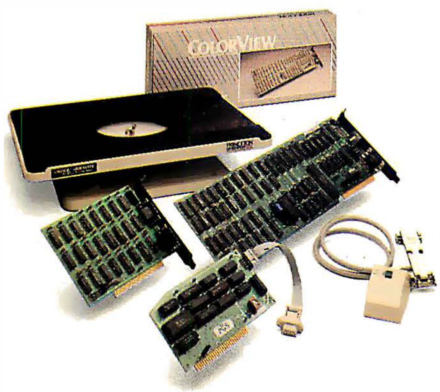
HX-9/9E. Nine inch, high resolution RGB monitor non-interlaced -.28mm dot pitch tube -9E compatible with IBM Enhanced Graphics Adapter -Nonglare screen -Green/amber switch -Apple/IBM colors - Etched dark glass screen -**$650/$750** (9E)



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Inquiry 288

Color Fox

Scottsdale Systems enhances Sanyo's MBC-555

BY JOHN D. UNGER

Scottsdale Systems has taken the basic Sanyo MBC-555 computer and put it together with some major hardware upgrades to create the Silver Fox. Scottsdale has replaced the 40-track double-sided double-density (DSDD) disk drives with 80-track double-sided quad-density (DSQD) drives for a formatted disk capacity of 800K bytes per drive. Included with the Silver Fox is Sanyo's video RAM (random-access read/write memory) expansion board, which makes the computer much more IBM PC-compatible than the standard Sanyo MBC-555 and allows it to run Lotus 1-2-3 and other PC-compatible software. Besides the packages normally bundled with the Sanyo MBC-555, Scottsdale Systems adds more programs, including the new operating system needed to use the high-capacity disk drives and the video board.

Scottsdale Systems has also added an NEC color monitor to the basic Silver Fox and dubbed this combination the Color Fox. The Color Fox is the model I review in this article, and unless otherwise stated, the only difference between the Silver Fox and the Color Fox is the monitor.

What you get when you buy a Color Fox is a complete computer system with sufficient software to carry out all the most common tasks that a microcomputer is called upon to do: word processing, spreadsheets, database management, and running BASIC programs. However, the Color Fox cannot be considered a "true" IBM PC-compatible machine like the Compaq or Zenith Z-150. If you must have some special piece of software for your specific application, make sure there is a version that runs on the Color Fox, either with or without the video RAM expansion board.

John D. Unger (POB 95, Hamilton, VA 22068) is a geophysicist for the U.S. government. At work he investigates the causes of earthquakes; at home he tries to keep up with the programming efforts of his two teenaged sons.

HARDWARE

The principal enhancements to the Color Fox are hardware, so I will spend most of the review discussing these aspects. As I mentioned, the basic hardware of the Color Fox is pure Sanyo. In spite of the new label on the front of the computer (see the photo in the "At a Glance" section), the plate with the serial number on the rear of the review machine reads "Sanyo MBC-555-2."

The most apparent difference between the Color Fox and the Sanyo MBC-555 is the substitution of the standard DSDD disk drives with two DSQD drives. The drives, TEAC model FD-55F, can read and write disks formatted in all the standard MS-DOS 40-track formats, either single- or double-sided. With a special operating system from Scottsdale Systems, the drives can read and write disks formatted with either 8, 9, or 10 sectors and 80 tracks for a maximum capacity of 800K bytes per drive. This special operating system is essentially a modification of MS-DOS 2.11 written for the Sanyo. It's called HAGEN-DOS. The computer must be booted with this special operating system to take advantage of the increased disk capacity.

These high-density drives are significantly noisier than either the original single-sided or the DSDD TEAC FD-55B drives I now have in my Sanyo MBC-555. The noise appears to come from the stepper motor as it moves the heads from track to track, but it does not seem to affect the performance of the drives.

I had not realized just how much you can store on one 5¼-inch disk when it has a capacity of 800K bytes. In fact, I began to make good use of MS-DOS's tree directory structure, which is normally useful only on hard disks, and partitioned my files into different subdirectories. While Scottsdale Systems recommends disks certified at 96 tracks per inch, I did not use anything other than disks certified for DSDD use in the quad-density drives, and I had no failures formatting even "generic" DSDD disks in 80-track format.

The Sanyo video RAM board is an expansion board that was introduced about a year after the MBC-555 came on the market.

(continued)

HAGEN-DOS *looks and acts just like* MS-DOS 2.11 *except for the format program.*

Sanyo introduced this option to enable its computer to run Lotus 1-2-3; as a side benefit, the Color Fox and any other Sanyo MBC-555 with the board installed can run other IBM PC graphics software as well.

Technically, together with the special operating system, the video RAM board duplicates the 16K bytes of memory that is permanently set aside in the IBM PC for direct memory access by the graphics display. This tactic is necessary because the Sanyo MBC-555 uses a different section of memory for this purpose. The location of video RAM in the Sanyo also depends upon how much memory you have installed in your computer. Just to complicate things further, the display is "mapped" from RAM to the screen coordinates differently in the Sanyo than in the IBM PC.

The video RAM board mounts inside the case of the Color Fox and is electrically connected to the computer through the single expansion bus on the motherboard. Utilizing the video RAM board's capabilities can be somewhat awkward. The Color Fox comes with two versions of HAGEN-DOS. One version is for use when running the "straight" Sanyo memory model (that is, without the video board enabled). The other version is for use with software that requires the video RAM board. Also, you have to switch the monitor from its normal output port on the rear of the computer to a different port on the expansion board. Initially, this was quite a chore because the two ports have different types of sockets, so I was switching cables back and forth all the time. Scottsdale Systems now supplies a twin-lead cable connected to a two-position switch (standard with the Color Fox only). Still, when you want to change from using an application that requires the video board to one that doesn't, you must reboot the system with the proper version of HAGEN-DOS, switch the monitor cable selector, and then change the monitor SYNC setting from positive to negative.

I was disappointed with the NEC color monitor. There were no problems running graphics or games in color; the clarity and color separation in graphics mode were very good. My problems stem from trying to read text on the screen. The clarity and resolution of text were poor enough that, for the first time, I did not write the entire review on the actual computer I was reviewing. I lay the blame chiefly on the monitor because the Color Fox's text quality on a normal high-resolution monochrome monitor is quite acceptable. The character set is very similar to that formed on an IBM PC in graphics mode.

The overall quality of the display while operating in IBM PC-compatible mode with the video RAM board is clearly worse than the standard display mode. The screen scrolls in a jerky fashion, and the scrolling is accompanied by streaking and blurring on the display.

The Color Fox has all the open RAM sockets on its motherboard filled, giving it a total of 256K bytes of RAM. This is the maximum memory for the Sanyo and the Color Fox.

SOFTWARE

To run the bundled MicroPro and IUS software, or when running programs using Sanyo BASIC, you need to boot up under the version of HAGEN-DOS that disables the video RAM board. To run IBM PC-compatible software and the version of GW-BASIC included with the video board, you need to boot up under the version of HAGEN-DOS that enables the video board. Both operating systems support the quad-density disk drives and both include some nice utility programs not supplied by Sanyo, including a RAM-disk program and a screen-dump routine. The two operating systems and their extra utility programs are products of A-OK Computers and can be obtained separately and used with a normal Sanyo MBC-555. (A-OK Computers is located at 816 Easley St., Silver Spring, MD 20910; telephone (301) 588-8446.)

HAGEN-DOS looks and acts just like plain MS-DOS 2.11 except for the format program, which is more user-friendly and includes the option to format disks in quad-density. I had no problem reading from or writing to disks created in either single- or double-sided double-density format on the Color Fox or on any other MS-DOS or PC-DOS machine.

Scottsdale Systems spices up the Color Fox with three major pieces of bundled software not included with the Sanyo MBC-555. The programs are Spell, a spelling proofreader by Software Toolworks; Filebase, a simple database manager by EWDP Software; and Mail Track I, a mailing-list program by Sapana Micro Software. I found the best of the lot to be Spell. It runs faster and is easier to use than SpellStar, which is included with the WordStar series that comes with the Color Fox. Spell has an effective dictionary of more than 50,000 words and runs independently of the word-processing program you are using. It has no problems working with text files created by WordStar or with normal ASCII files, but it may not work with files written on some word processors.

BENCHMARKS

The benchmarks for the Color Fox are somewhat more complex than usual. Because the video RAM board changes the character of the computer completely, I ran each benchmark both with and without the board enabled. I used GW-BASIC for the BASIC benchmarks run with the video board and Sanyo BASIC without the video board. The numbers in the benchmarks do not tell the whole story, however. While changing from page to page or moving the cursor around the page in WordStar, the video-board version of this program runs much faster than the standard

(continued)

AT A GLANCE

Name
Color Fox

Type
Enhanced Sanyo MBC-555 with color monitor

Company
Scottsdale Systems Ltd.
617 North Scottsdale Rd. #B
Scottsdale, AZ 85257
(602) 941-5856

Size
15 by 14½ by 4⅖ inches; 21 pounds

Components
Processor: 8088 at 3.6 MHz
Memory: 256K dynamic RAM standard
Mass storage: Two TEAC FD-55F double-sided quad-density 5¼-inch drives; 800K capacity per drive
Display: NEC JC-1460DA color display; 13-inch diagonal screen; 80-column by 25-line text; 320 by 200 graphics in IBM PC mode; 640 by 200 without video RAM; 640 by 400 with monochrome monitor
Keyboard: Detached QWERTY with five function keys and numeric pad
Interfaces: Parallel printer port, monochrome and color RGB ports on both motherboard and video board

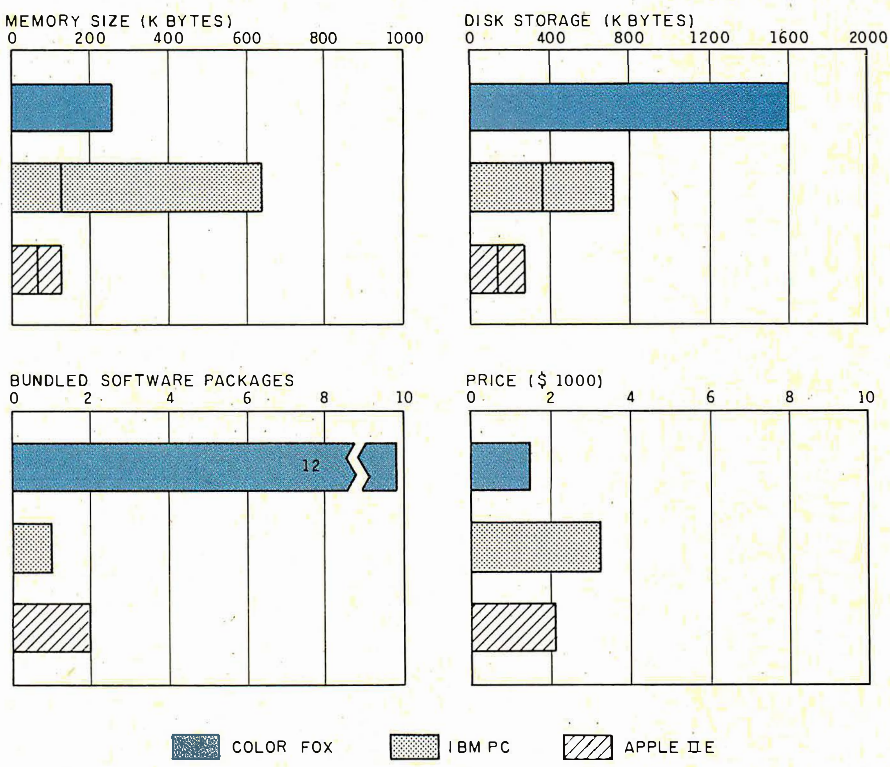
Software
HAGEN-DOS (similar to MS-DOS 2.11), Sanyo BASIC, GW-BASIC, WordStar, SpellStar, MailMerge, InfoStar, CalcStar, Easywriter, Spell, Filebase, and Mail Track I

Options
RS-232C serial port

Documentation
Sanyo operator's guide, manuals for all software except GW-BASIC

Price
$1497

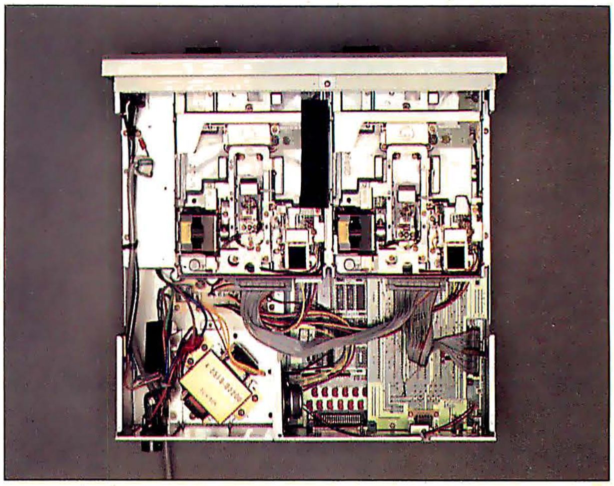




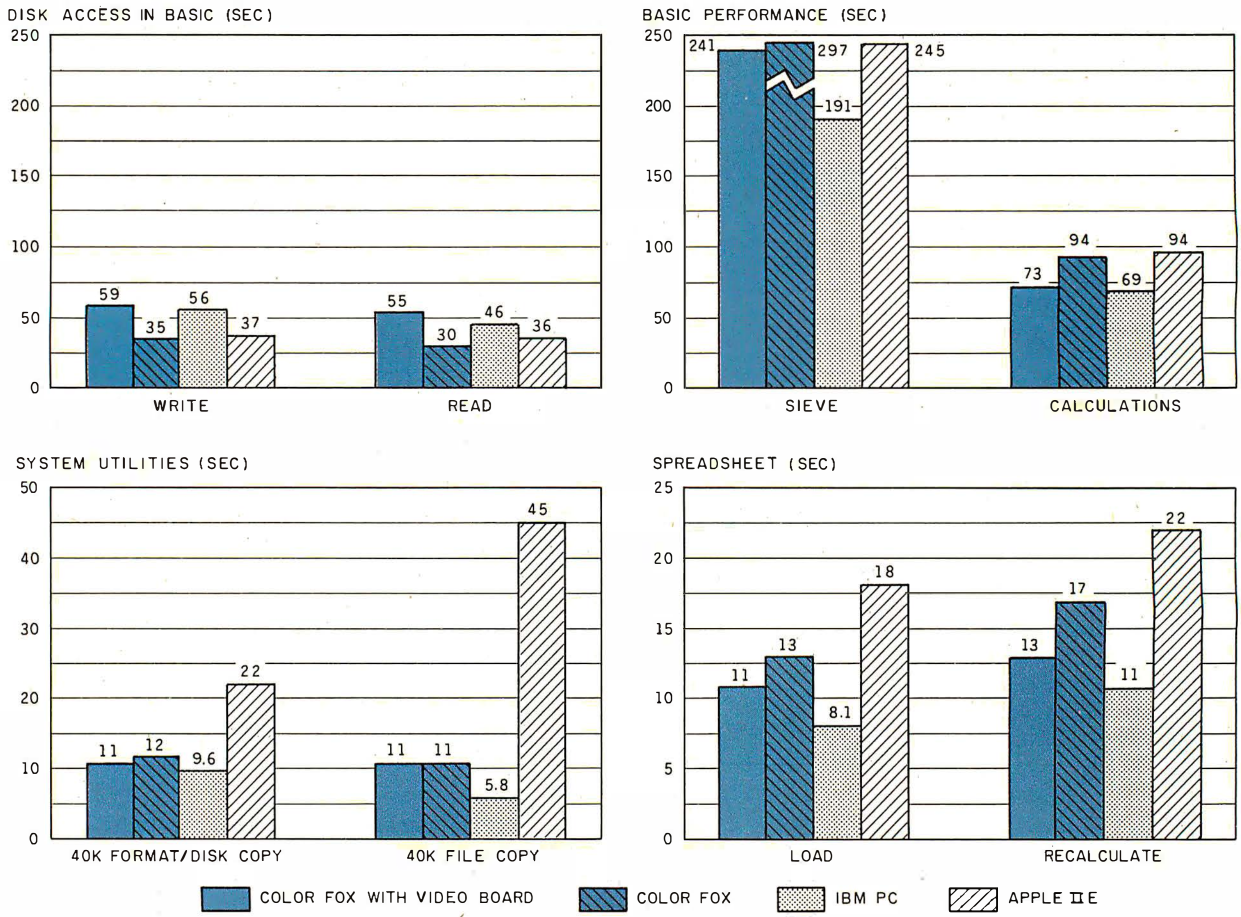
The Memory Size graph shows the standard and optional memory for the computers under comparison. The Disk Storage graph shows the highest capacity of one and two floppy-disk drives for each system. The Bundled Software Packages graph shows the number of packages included with each system. The Price graph shows the list price of a system with two high-capacity floppy-disk drives, a monochrome monitor, graphics and color-display capability, a printer port and a serial port, 256K bytes of memory (64K bytes for 8-bit systems), the standard operating system for the computers, and their standard BASIC interpreters.



The rear of the Silver Fox. An NEC color monitor distinguishes the Color Fox from the Silver Fox. Also, a twin-lead cable comes with the Color Fox to facilitate swapping between the RGB plugs on the motherboard and on the video RAM expansion board.



The inside of the Silver Fox. Notice the video RAM expansion board in the lower right corner.



In the Disk Access in BASIC graph, a 64K-byte sequential text file was written to a blank floppy disk and then read. (For the program listings, see the June 1984 BYTE, page 327, and October 1984, page 33.) In the BASIC Performance graph, the Sieve column shows how long it takes to run one iteration of the Sieve of Eratosthenes. The Calculations column shows how long it takes to do 10,000 multiplication and 10,000 division operations using single-precision numbers. The System Utilities graph shows how long it takes to format and copy a disk (adjusted time for 40K bytes of disk data) and to transfer a 40K-byte file using the system utilities. The Spreadsheet graph shows how long the computers take to load and recalculate a 25-by 25-cell Multiplan spreadsheet where each cell equals 1.001 times the cell to its left. The tests for the Color Fox with the video board were done with GW-BASIC; the Color Fox without the video board was tested with Sanyo BASIC. The tests for the Apple IIe were done with the ProDOS operating system (except for the spreadsheet test, which was done with DOS 3.3). The IBM PC was tested with PC-DOS 2.0.

Sanyo version. This is because the video board can take advantage of direct video memory input/output, while the version of WordStar configured for the Sanyo or for the Color Fox without the video board enabled uses slower BIOS (basic input/output system) screen-scrolling routines to move through the text.

Conclusion

The Color Fox is an impressive package of hardware and software offered at an attractive price. Scottsdale Systems has taken a powerful yet inexpensive system, the Sanyo MBC-555, and made it more powerful, more IBM PC-compatible, and added even more software in the bargain.

The hardware enhancements that create the Color Fox from a Sanyo could be done by anyone. However, even if you bought the basic computer and the various components at bargain prices, you'd still end up paying about $300 to $400 more for your system than for the Color Fox.

On the negative side of things, the high-density disk drives are somewhat noisy, and the display quality leaves something to be desired, especially when using the video RAM board in text mode.

The Color Fox comes with a limited one-year warranty from Scottsdale Systems. Easterners may not be comfortable dealing with a company located as far away as Arizona. They might prefer to do business with one just around the corner. However, as far as I know, Scottsdale Systems is the only place to go if you want to buy the Color Fox. The people I talked to there were courteous and knowledgeable. Also, the basic core of the Color Fox, the Sanyo MBC-555, has proven to be a rugged and reliable computer during the past year and a half. The owner of a Color Fox should have no trouble obtaining post-warranty service for the machine from one of the many dealers set up to work on the Sanyo. ■

Editor's note: For a review of the Sanyo MBC-550/MBC-555, see page 270 of the August 1984 BYTE.

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Inquiry 251

Eco-C88 C Compiler

An inexpensive MS-DOS C compiler

BY DAVID D. CLARK

In the spring of 1983 I noticed advertisements for a new C compiler for Z80 CP/M systems. I had a couple of C subset compilers at that time but wanted one that could perform floating-point arithmetic. That summer I purchased Eco-C version 1.51. I was rather disappointed with it as I indicated in a BYTE review (see "Two More Versions of C for CP/M," May 1984, page 246). Since I wrote that review, Ecosoft has made substantial improvements to the product. It became so good that I bought additional copies for my place of work and now recommend it without reservation.

Since the original review, I have purchased a Zenith Z-150 IBM PC-compatible computer. I saw that Ecosoft developed a version of its compiler for MS-DOS systems, but at $250 it was more than I could afford. When Ecosoft announced the new price of $49.95, I placed my order.

USING ECO-C88

Installing the compiler is easy. The batch-processing files supplied on the two distribution disks perform the installation automatically. There are two versions: INSTALLF.BAT for systems with two 360K-byte floppy-disk drives and INSTALLH.BAT for systems with a hard disk. The installation process is different from the sequence described in the user's manual because of a change in file sizes; it is documented in a README file on one of the distribution disks. On a floppy-disk system, the compiler and library are placed on one disk, while the header files, cc utility, linker, and editor of your choice are placed on the other. On a hard disk, the files are distributed among several subdirectories.

After installation is complete, you can create a C program using your own text editor. The full C syntax as defined in Kernighan and Ritchie (*The C Programming Language* by Brian W. Kernighan and Dennis M. Ritchie, Prentice-Hall, 1978) is supported, with the exception of bit fields and the #line macro preprocessor directive. Only the small memory model is supported, so programs contain a maximum of 64K bytes of code and 64K bytes of data. This is usually more than adequate. (See the text box "Eco-C88: An Update" on page 314 for the latest information.)

Compiling a program is simple; you type cc followed by the program name. The cc program is not actually part of the compiler proper. It is an auxiliary utility program that controls the flow of the compilation and accepts several options to alter its normal actions. One pleasant feature is the presence of a simple make command. For those not familiar with a UNIX version of the utility, the make command takes care of the compiling and linking of files that make up a program. It will only recompile those modules that have been altered since the last time you ran the program. The cc utility is also provided in source form, so you can customize it to fit particular system configurations. [*Editor's note: The* cc *utility requires* DOS 2.21 *or higher to run.*]

The cc utility makes automatic operation of the compiler convenient, but it is possible to individually invoke each of the compiler's passes. These passes consist of the preprocessor (XP.EXE), parser (XC.EXE), optimizer (XOP.EXE), code generator (XM.EXE), and assembler (XASM.EXE). An error pass (CE.EXE) is called automatically if one of the other passes detects an error. The compiler's output is an .OBJ-type object module that you must then link with routines from the library to produce an executable .EXE file. Although there is a separate assembler pass, it does not accept a human-readable text file as input. All communication between the separate parts of the compiler is accomplished by reading and writing data files (*.cwk) that are automatically created and erased as the programs run.

Error handling is performed just as it is in the Z80 version of the compiler, and it's one of my biggest gripes. If the compiler

(continued)

David D. Clark *is a research chemist working at the Research and Development Center of the Colgate-Palmolive Company. He has a B.A. in chemistry from Indiana Central University and a Ph.D. in biological chemistry from the University of Nebraska. He can be reached at* 126 Birchview Dr., Piscataway, NJ 08854.

AT A GLANCE

Name
Eco-C88 1.55

Company
Ecosoft Inc.
6413 North College Ave.
Indianapolis, IN 46220
(317) 255-6476

Necessary Hardware
MS-DOS 2.0 (or higher) 8088-based computer with 256K bytes of memory and two 360K-byte floppy-disk drives or one floppy-disk and one hard-disk drive

Documentation
92-page loose-leaf user's manual in a slip-cover binder

Price
$49.95

detects an error in the preprocessor, it informs you of what occurred but not always of where. For example, if it detects an unclosed comment, the compiler tells you that it is on the last line of the file and that a comment is not closed. It gives you no idea of where the offending comment starts. The only solution I have found is to place dummy #include directives in the file and see how many the compiler includes. If the parser detects an error, it falls into one of two general types: a warning or a fatal error. When this occurs, the line number, character number in the line, and offending token are displayed as well as the error message. The line numbers do not seem to be particularly reliable, however. I have had two succeeding errors with different tokens report identical positions in the file. Furthermore, I can't find either with a text editor. The compiler continues through multiple warnings, but compilation stops after detection of a single fatal error.

The manual describes the compiler's operation with the cc program quite well but contains little description of how to use the individual programs that make up the compiler itself. Two compiler command-line options, h and d, are mentioned, but the manual does not state their purposes. From reading the source text for the cc program, you can deduce that the h command tells the compiler which directory to search for header files. The d option enables you to do a "command-line define," meaning you can define a symbol to the compiler from the command line. This would be useful for switching on or off conditionally compiled debugging code in the program. Although it is not mentioned in the manual, the com-

(continued)

piler accepts an n command-line option to disallow the use of nested comments in the source text.

THE LIBRARY

The library is included in object form only, but the source is available at extra cost ($15 according to the manual, $10 when I ordered). The library contains all the standard library routines you would expect after reading Kernighan and Ritchie. Additional groups of routines are for operating-system-dependent functions, terminal handling, and IBM-specific video routines. The library occupies about 150K bytes of disk space and, unlike the Z80 version, consists of only one file.

The floating-point routines can use an 8087 numeric coprocessor if one is available. If not, the software emulates the coprocessor's operations. The compiler determines the coprocessor's presence or absence by examining the value of an external variable, *_8087*. You can use this variable to force software emulation by setting it to FALSE. The software emulation insures that systems with and without the coprocessor will obtain the same results from a series of calculations.

An object-only version of the ISAM (indexed sequential-access method) functions is also available for $15.

BENCHMARKS

I used six benchmark programs when evaluating Eco-C88. Several are presented in listings 1 through 5; the results are summarized in table 1. For these evaluations, I used a Zenith Z-150, an IBM PC-compatible computer with 320K bytes of memory and two 360K-byte double-sided double-density floppy-disk drives. I performed compilations using the cc program previously described and the -nl command-line option to prevent automatic linking. I did linking by invoking the MS-DOS linker manually. I did all timing by hand using a stop watch and took the average of three measurements. File sizes are those given by the MS-DOS command DIR.

The Empty program in listing 1 pro-

Table 1: *A summary of the benchmark results in seconds. All timing was done by hand. The measurements recorded are an average of three. The compile/assemble times were most variable and seemed to depend on the history of file operations on the disk.*

Program	Compile/Assemble	Link	Execute	Size
Empty	59	26	—	962 bytes
Sieve	63	71	11	7894 bytes
Fib	67	68	43	7876 bytes
Deref	65	66	10	7896 bytes
Factor	70	73	18	8760 bytes
Savage	61	108	449	14,577 bytes

Listing 1: *The Empty benchmark tests for the system overhead required to create any program regardless of its useful content.*

```
/*
** empty.c — benchmark to get compile, assemble, link, and library
** overhead
*/

main( )
{
}
```

Listing 2: *A corrected version of the Deref benchmark program, which examines the speed of pointer dereferencing.*

```
/*
**      deref.c — benchmark program to examine the efficiency
** of pointer dereferencing
*/

#define LOOPS     (unsigned) 50000          /* how many loops */
#define BELL      7         /* ASCII bell character */

struct cptr1 {
        char *************************ptr1;
        };

main()
{
unsigned i;
char yekdorb;
struct cptr1 *********************pointer;

        printf("%u loops \ n", LOOPS);

        for (i = 0; i < = LOOPS; i+ +)
                yekdorb = *********************
                        (*********************pointer).ptr1;

        printf("%cfinished \ n", BELL);
        exit(0);
}
```

Listing 3: *The Factor benchmark tests the implementation of* long ints. *It uses the Pollard rho algorithm to find a factor of a large integer.*

```
/*
**      factor.c — a long integer benchmark in C
*/
#include        "stdio.h"
#define BIGNMBR 1394761         /* 1181*1181, number to be factored
*/
long p, x, y, cnt;
/*
**      gcd — return the greatest common divisor of a and b
*/
long gcd(a, b)
long a, b;
{
long q, r;
        if (b < 0)
                b = -b;
        if (a < 0)
                a = -a;
        if (a > 0)
        {
                b = b % a;
                if (b == 0)
                        r = 0;
                else
                        r = 1;
                while (r > 0)
                {
                        q = a/b;
                        r = a - q*b;
                        a = b;
                        b = r;
                }
        }
        return (a);
}
main()
{
        puts("Factoring...");
        p = BIGNMBR;
        cnt = 0;
        x = 3;
        y = 3;
        while (gcd(y - x, p) < 2)
        {
                cnt++;  /* Pascal or Modula can use Succ or INC */
                x = (x*x + 2) % p;
                y = (y*y + 2) % p;
                y = (y*y + 2) % p;      /* no, this is not a mistake
*/
        }
        printf("A factor of %ld is %ld\n", p, gcd(y - x, p));
        printf("It took %ld iterations\n\n", cnt);
}
```

On a system that uses floppy disks, most of the time involved in compiling small programs is used by disk input/output.

vides an estimate of the overhead required just to compile and link a program and the minimum memory necessary to create an executable file regardless of its useful content. The results in table 1 lend support to the conclusion that, at least on a floppy-disk-based system, most of the time involved in compiling small programs is used by disk I/O (input/output).

The Sieve of Eratosthenes is *the* high-level-language benchmark for microcomputers. It uses an algorithm to find all the prime numbers between 3 and 16,381.

The Fib program calculates a series of Fibonacci numbers using a highly recursive algorithm. Because of the recursive function calls, this program gives a good estimate of how well a particular language implementation performs function calls. (Listings for the Sieve and Fib programs appear in May 1984 BYTE, pages 250 and 252, or you can download them from BYTEnet Listings at (617) 861-9764.)

When I wrote the review of Eco-C's CP/M version, I was new to C. I heard that pointers were an important part of the language and wanted to write a benchmark that could discern differences in the dereferencing of pointer variables. The result is the Deref benchmark in listing 2. Since the appearance of the first review, others have pointed out to me that the original program has a flaw. The error was in the declaration of

```
#define LOOPS     50000
```

My intention was that LOOPS be an

(continued)

unsigned integer. However, in the body of the program, that 50000 should be interpreted by compilers as a long int. If the declaration had defined LOOPS as a hexadecimal C350 or as an octal value, the listing would have been fine. However, according to Appendix A of Kernighan and Ritchie, a decimal number greater than the largest positive integer should be interpreted as a long integer. This causes problems for some compilers with the printf statement at the end of the program. Some compilers work because of the way the standard library is implemented. C subset compilers generally have no difficulties, since they usually do not implement long integers.

In order to fix the program, you can simply replace the statement in question with

```
#define LOOPS      (unsigned) 50000
```

Eco-C88 compiled and worked correctly with both versions. The version with the cast to unsigned produced a slightly smaller program that ran substantially faster.

Most compilers that fail to make it through this program do so because of the depth of indirection. It has been argued that there is no practical analog for such a construct in a program and that the proposed ANSI C standard will require only six levels of indirection. That might be true, but the syntax summary of the language in Kernighan and Ritchie specifies that indirection can be of any depth. In my opinion, the program is flawed on aesthetic grounds since what is pointed to through all those levels of indirection is a random byte of memory. If someone can devise a benchmark that has such a high proportion of dereferencing operations and is more practical, I'd like to hear about it.

The Factor program in listing 3 tests the efficiency of the implementation of long integers. It is based on a Pascal program by Richard E. Crandall (*Pascal Applications for Sciences*, John Wiley & Sons, 1983). It uses the Pollard rho algorithm to find factors of large numbers.

The program operates under the assumption that the number is indeed factorable. If given a prime number to operate on, the program will not return. The choice of BIGNMBR is arbitrary. It gives an easily measurable execution time. The program uses many of the arithmetic operators as well as long function parameters and function-return values. It gives a fairly well rounded indication of the efficiency with which long integers are implemented in a language.

The Savage program in listing 4 tests the speed and accuracy of floating-point calculations. This is a C version of a program originally proposed by Bill Savage in the September 1983 issue of *Dr. Dobb's Journal* ("16-Bit Software Toolbox" by Ray Duncan, page 120). The correct result for the pro-

(continued)

Listing 4: *The Savage floating-point benchmark. The program tests the speed and accuracy of floating-point calculations.*

```
/*
** savage.c — floating point speed and accuracy test. C version
** derived from BASIC version that appeared in Dr. Dobb's Journal,
** September 1983, pages 120-122.
*/

#define ILOOP   2500

extern double tan(), atan(), exp(), log(), sqrt();

main()
{
int i;
double a;
        printf("start\n");
        a = 1.0;
        for (i = 1; i <= (ILOOP-1); i++)
                a = tan(atan(exp(log(sqrt(a*a))))) + 1.0;
        printf("a = %20.14e\n", a);
        printf("done\n");
}
```

Listing 5: *This apparently innocuous Fopentst program will never run correctly, even if the correct file is present in the default directory, because of the register handling used by* Eco-C88.

```
/*
**  fopentst.c — test the operation of the fopen() function
*/

#include        "stdio.h"

main()
{
FILE *fp;

        if ((fp = fopen("MYTEXT.TXT", "w")) == NULL)
        {
                puts("Can't open MYTEXT.TXT\n");
                exit(-1);
        }
        puts("Successfully opened MYTEXT.TXT\n");
}
```


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The Eco-C88 compiler is rather strict in its adherence to the C language as defined by Kernighan and Ritchie.

gram is 2500. When I ran the program, it printed a final value of 2.49999999968640E3, or an error of about one part in a billion. From the results in table 1, it would appear that Eco-C88 is rather slow. This is not entirely true. As I've mentioned, the software floating-point routines emulate the 8087 coprocessor. This means that doubles are 8-byte quantities with a dynamic range of about $+/-10^{308}$. That means you can calculate a number as large as 170 factorial without overflow. The other point to note is the accuracy maintained while calculating transcendental functions. Many implementations will only approximate such functions to six or seven significant digits.

From past tests of MS-DOS C compilers, the results for the comparable benchmarks seem to show that Eco-C88 is one of the fastest and produces relatively compact code. A possible exception is in the area of floating-point calculations where the software emulation of the 8087 might cost the compiler in speed. I am not aware of any directly comparable results for the long-integer benchmark, but I would say that performance in this area is quite adequate. The difference between the 16-bit MS-DOS version of the compiler and its 8-bit counterpart is quite pronounced, even though the 8-bit version is the fastest I have tested.

Another interesting point is that, although the Empty benchmark produced a code file of less than 1K byte, if you write a program that actually does anything, it requires a minimum of about 8K bytes. Overhead is about 1 minute due to disk thrashing on a floppy-based system.

Consider the Fopentst program in listing 5. It looks perfectly legal. As a matter of fact, it will compile and link without error. However, it will never be able to open the file, even if it is present in the default directory. The fopen() function is declared as a function returning a pointer to a variable of type FILE in the source code for the library functions. It is that way on almost all compilers. However, in the program listing, the type of the return value for the function is not declared and the compiler correctly assumes it to be of type int. The problem occurs because of the way Eco-C88 allocates registers: All return values of type int are returned in the AX register. All pointers are returned in the BX register. In order to get the program to work, the declaration

```
FILE *fopen();
```

must appear in the program or the return value gets lost. I should emphasize that nothing is wrong with the way Eco-C88 handles this. It is good programming practice to make such declarations, but it is unusual. Handling register usage in this way probably allows for certain speed and size optimizations not possible if pointer results were returned in the same registers as char, int, and unsigned results. I first ran across this problem when porting programs compiled on UNIX, MS-DOS, and CP/M systems. Mention of this in the manual would have been helpful.

Conclusion

Eco-C88 is a high-quality package, particularly at its new price. It is comparable to systems costing much more. It is convenient to use, works well, and produces acceptably compact and fast programs. The compiler is rather strict in its adherence to the language as defined by Kernighan and Ritchie, almost authoritarian for a C compiler.

A few elements do annoy me, mostly in the area of compiler error handling. Also, because of the large number of passes involved, the compiler spends a lot of time reading and writing disk files. It might be nice to be able to examine assembly-language output occasionally, but I have not really missed it. You cannot easily use the system to create programs that manipulate huge amounts of data in memory because only the small memory model is supported, allowing 64K-byte programs and 64K-byte data segments. However, all in all I am more than satisfied. ■

Eco-C88: An Update

Since the evaluation of Eco-C88 by David D. Clark, Ecosoft has made a number of revisions to its C compiler. The version now available is 2.81, as opposed to the 1.55 version reviewed.

The C library has been split into three separate libraries to provide support as needed. These files are ECOC.LIB (standard C functions), ECOT.LIB (transcendental math support), and ECOM.LIB (expanded memory support). The standard library, ECOC.LIB, has more functions, such as fgetc and fputc. The memory library, ECOM.LIB, lets you address outside of 64K bytes of data memory, but it does not support large models.

The cc utility has more options, some that are documented in a new manual, some in a README.DOC file.

The -a option, where supplied to the cc utility or the assembler-pass module XASM.EXE, produces human-readable assembly-code files. The MS-DOS assembler, MASM, can read these files.

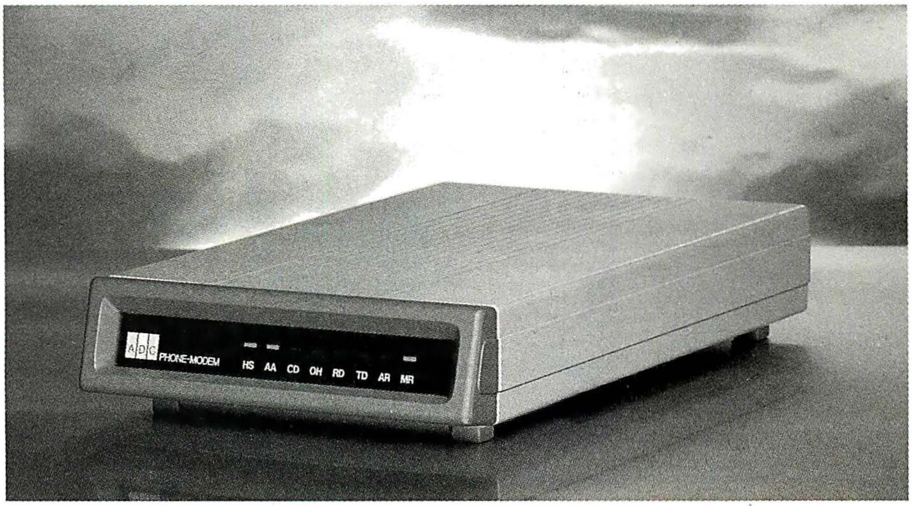
Error messages can be directed to an output file using the -e<filename> option, and the line numbers for the error messages are accurate. In addition, enumerated data typing is supported.

A paperback book has replaced the loose-leaf binder for the new Eco-C88 manual.

1200 Baud Smart Duck

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By Drew Kaplan



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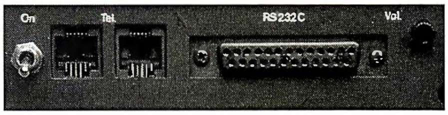
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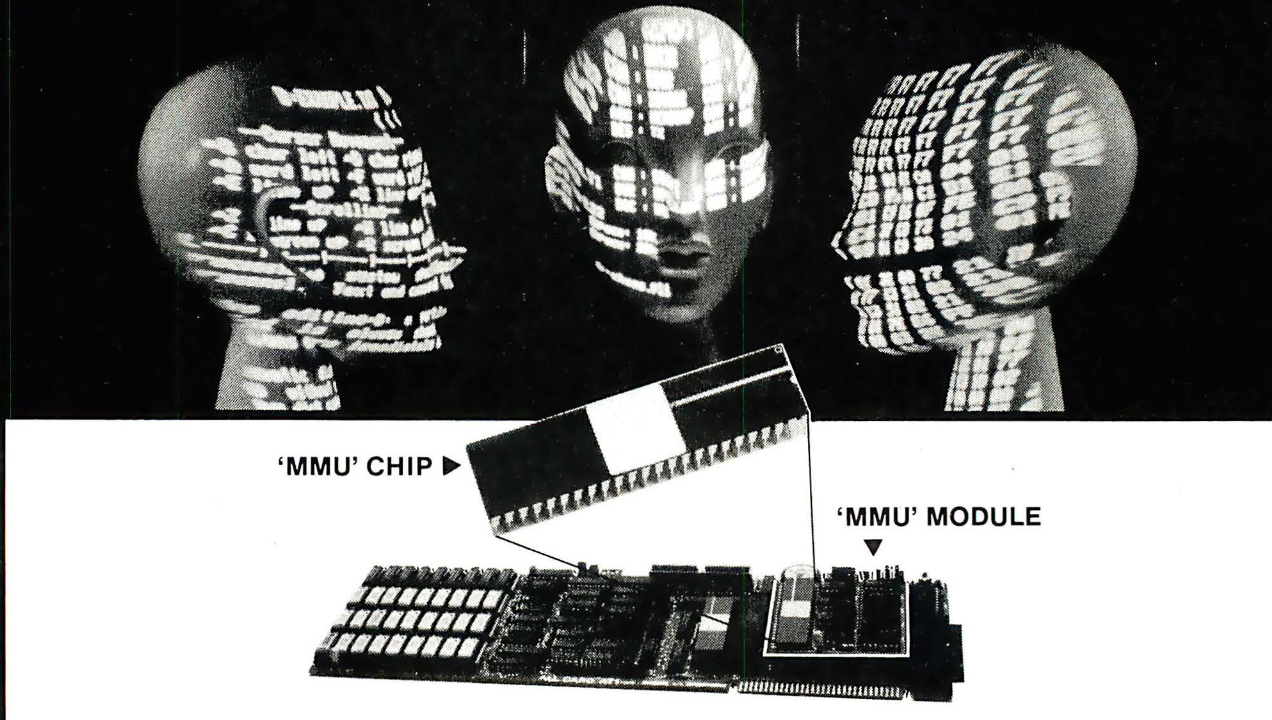
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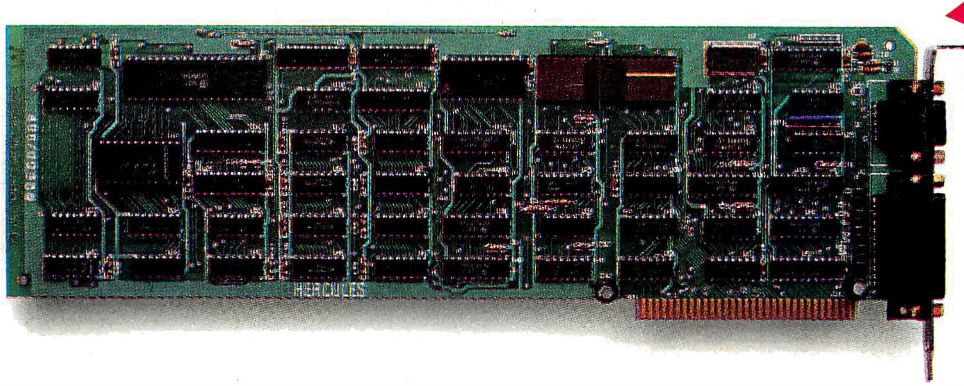
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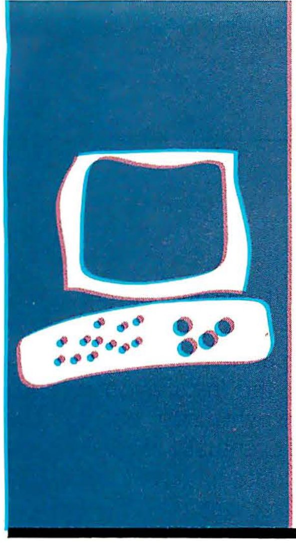
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H·A·R·D·W·A·R·E R·E·V·I·E·W

Inside The Sider

A hard-disk drive for the Apple II+, IIe

BY DOUGLAS E. HALL

To run my own business as a microcomputer consultant for nonprofit organizations, it was clear that I would need a hard disk for storing my word-processing, spreadsheet, database, and program files, which filled more than 40 floppy disks.

A mailer I received from First Class Peripherals advertised a 10-megabyte hard-disk system for Apple II computers. Called The Sider, it sold for only $695. Not only was the price right, but the company offered a 15-day trial period during which I could return it with no questions asked. That seemed unprecedented for a piece of sophisticated computer equipment.

The disk drive is about the size of a shoebox, measuring 7.5 by 3.5 by 16 inches. The well-padded package from First Class contained the drive, interface board, installation manual, cable, installation software, and miscellaneous hardware.

INSTALLING THE HARDWARE

Although I have degrees in electrical engineering and once designed and wire-wrapped my own homebrew computer, that background was not adequate to help me determine the difference between an "anchor screw" and a "retaining screw," both of which were involved in installing the cable-clamp assembly to the back of my Apple IIe. First Class could have made the task easier by including a few more diagrams of hardware-installation steps in the manual. It would also help to have a diagram showing and naming each part and noting whether it is for the Apple II+, IIe, or both. Nevertheless, within 45 minutes I had the hardware connected. When the computer and disk were plugged in and turned on, the drive began to hum, and I figured I had at least approximated the correct cable installation.

INSTALLING OPERATING SYSTEMS

The Sider is partitioned to hold up to four operating systems: DOS 3.3, Pascal, ProDOS, and CP/M. You have to decide on the amount of disk space you want to set aside for each system, however, and then follow the step-by-step procedures in the manual. I installed only DOS 3.3 and CP/M. The "dynamic partitioning screen" for dividing the disk into sections for each operating system was confusing to use. Eventually it became clear that I had to adjust ProDOS for maximum partition size (even though I didn't need it at all) as a step along the way to dividing up the disk into CP/M and DOS 3.3 areas. That didn't make a lot of sense to me, but that's the way it had to be done.

In contrast to the Davong 15-megabyte hard disk, which I had used for nearly two years earlier, The Sider requires the entire disk to be partitioned during installation. You are not allowed to leave part of the disk undesignated as to operating system and assign it later when your actual need for space becomes more apparent. This forces you to make better estimates as to your space needs and could possibly cause problems later. In my case, if I decide next month that I want to install Pascal, there will be no hard-disk space available for Pascal files even though I may have lots of unused CP/M space. The only solution is to repartition the disk, install the operating system again, and then restore all the files to the disk from backup floppy disks. It would have been better to allow some of the disk space to remain unassigned until needed.

Once I had partitioned the disk, my next step was to break each partition into volumes as desired. Again the manual was not very satisfactory. It stated that "DOS is divided into small volumes (DOS-SV) and large volumes (DOS-LV)," without indicating what the actual sizes or limitations on use were for either. After I had guessed at what I might need, I was ready to format the disk and install my operating systems. I followed the manual meticulously and all went well. That isn't to say I understood all that was happening. For example, during the process

(continued)

Douglas E. Hall has B.S. and M.S. degrees in electrical engineering from Stanford University. He currently runs his own microcomputer consulting business. He can be contacted at MicroCraft, Lane Road, Chichester, NH 03263.

AT A GLANCE

Name
The Sider

Type
10-megabyte external hard disk with controller card for Apple II+, IIe

Company
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3579 Highway 50 East
Carson City, NV 89701
(800) 538-1307
(702) 883-4000 in Nevada

Size
7.5 by 3.5 by 16 inches; 11 pounds

Necessary Hardware
Apple II+ or IIe with one floppy-disk drive, monitor, and 64K RAM

Necessary Software
One or more operating systems (DOS 3.3, CP/M, Pascal, or ProDOS)

Features
10 megabytes of formatted storage

Options
A second Sider can be daisy-chained

Documentation
53-page installation manual

Price
$595

a lot of screens appeared with information on "Pre Comp Cycle," "Control Byte," "Interleave," "DOS Bounds," and other items meaningless to me. The manual explains these screens by saying, "A series of screens describing the boundaries of each partition are displayed next." It would seem to me that if these screens are important or useful enough to appear at all, then some explanation should be provided. If they are not useful to the user, then why display them?

After an hour, I had completed the software installation. I turned everything off and rebooted. The Sider worked perfectly. The main menu appeared on my screen and I was able to drop into CP/M or DOS or run a program from either a floppy-disk drive or from The Sider.

UTILITY PROGRAMS

The Sider manual lists, but does not explain, the various utility programs that are provided. It seemed logical to me to use the Backup/Restore utility to copy my floppy-disk volumes and files onto the hard disk. I couldn't get it to work; it kept telling me that my floppy disks were not "library volumes." The manual contains not a hint about what this utility expects.

A call to First Class Peripherals' toll-free telephone number resulted in a discussion with a technician who said that he was not sure of the purpose of the Backup/Restore utility. He suggested that I use a different utility called Image Copy. He stated that First Class is preparing a user's manual to supplement the installation manual, that people who had bought The Sider would eventually receive a copy, but that no date had been set for its release. He also stated that he had only a handwritten set of engineering notes to use in assisting callers experiencing problems.

I used Image Copy and it worked well. It took 48 seconds to copy a 140K-byte DOS 3.3 floppy disk to a similar volume on the hard disk. (Don't make the mistake of using Image Copy in place of Apple's COPYA program to copy one floppy disk to another, however. COPYA requires 1 minute 28 seconds to complete that task; Image Copy requires more than 20 minutes.)

One especially handy utility is the Hard Disk Catalog. It automatically catalogs each DOS volume on the hard disk in sequence. It is extremely helpful in searching for a particular DOS 3.3 file. The program as provided was written in Applesoft, so I was able to make a simple modification to send the catalogs to the printer as well as to the screen.

One utility The Sider lacks is an import/export utility, which allows you to copy a file from one operating system to another. I need this to move text files from CP/M, where they were

(continued)



Photo 1: *Front view of The Sider hard-disk drive.*



Photo 2: *Rear view shows extra connection for daisy-chaining.*

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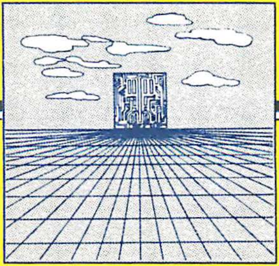
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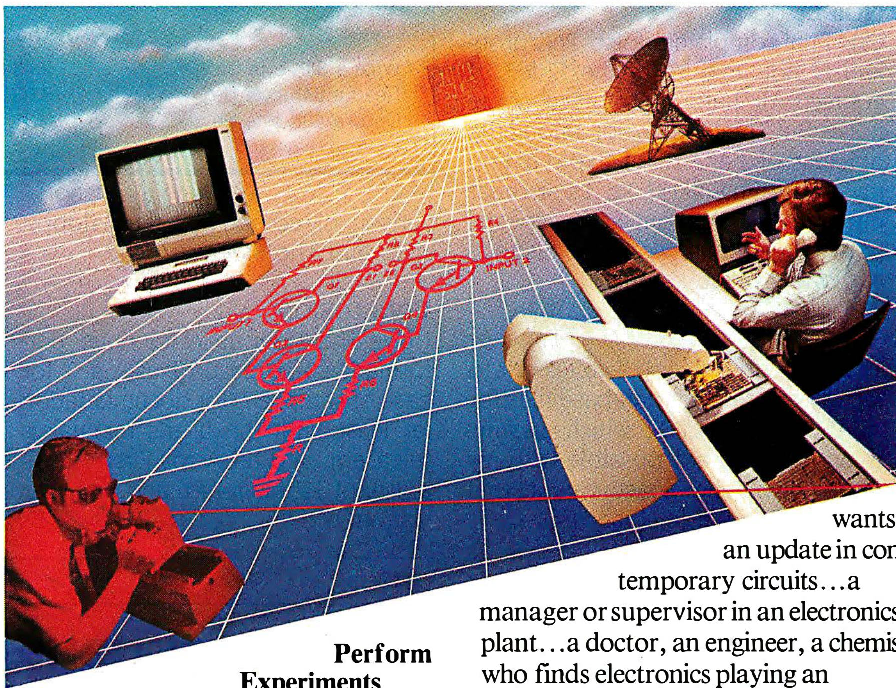
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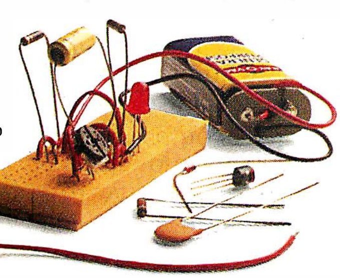
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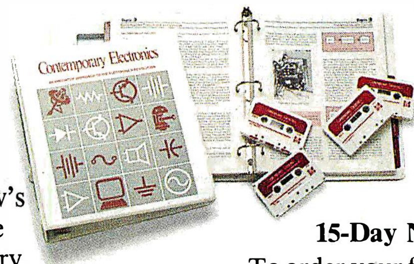
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created with dBASE II, to Apple DOS, where they will be used in a mail-merge routine. I'd pay $50 for such a utility. Is anybody at First Class listening?

NOISE

One final complaint: noise. This problem is not unique to The Sider, of course. All hard disks have some noise. But The Sider is not among the quietest of hard disks. I often find myself turning it off so I can hear myself think. Without some special noise insulation, it would be distracting in any office setting.

SPEED

The Sider does its job. I've used it to rapidly create large database files for dBASE II under CP/M, which is something that was not possible with my floppy disks. The measurements that are given in table 1 show a comparison of access times for floppy disks and The Sider.

Table 1: *Benchmark comparisons for The Sider hard-disk system and Apple's DuoDisk floppy-disk system. (See the June 1984 BYTE, pages 334 and 336, for details.) The benchmark programs were written in Applesoft BASIC. They were executed on an Apple IIe running DOS 3.3 and having 128K bytes of memory.*

	The Sider	Apple DuoDisk
Write a 64K-byte file	2:43	3:04
Read a 64K-byte file	3:03	3:35
Copy a 40K-byte file	:31	1:32

CONCLUSION

I give The Sider an A for price, performance, and ease of use; a C for ease of setup; a D for documentation (at least until the user's manual is released); and an A for First Class's policy of 15-day return and one-year warranty.

I have necessarily dwelt on the problems I see with The Sider. But the best summary of my evaluation is the answer to the question, "Did I return The Sider to First Class at the end of the 15-day free trial period for the promised full refund?" Definitely not. For the very attractive price of $695, I am willing to live with The Sider's limitations. [*Editor's note: The price has since fallen to $595.*] ■



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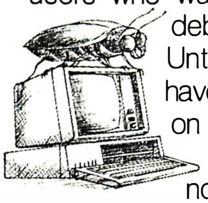
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XASM18	1802/1805	200.00	250.00
XASM48	8048/8041	200.00	250.00
XASM51	8051	200.00	250.00
XASM65	6502/65C02	200.00	250.00
XASM68	6800/01,6301	200.00	250.00
XASM75	NEC 7500	500.00	500.00
XASM85	8085	250.00	250.00
XASM400	COP400	300.00	300.00
XASMF8	F8/3870	300.00	300.00
XASMZ8	Z8	200.00	250.00
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H·A·R·D·W·A·R·E R·E·V·I·E·W

Advantage! for the AT

Add-on memory and I/O ports for the IBM PC AT

BY TJ BYERS

The architecture of the IBM PC AT's 16-bit-wide bus, although similar to that of the 8-bit-wide IBM PC bus, is different enough that standard IBM PC cards are not compatible with the AT in most cases. Consequently, a new generation of IBM enhancement products has been developed for this machine.

One of the more versatile multifunction boards for the AT is Advantage! from AST Research (see photo 1). Advantage!, which is among the first of the third-party products for the AT to appear on the market, closely resembles AST's SixPakPlus multifunction board for the IBM PC. Of course, there are differences.

First, you will notice that the AST clock/calendar is absent. Since the PC AT has an internal clock and calendar, AST has not duplicated it. Second, you can load the Advantage! with almost 10 times as much RAM (random-access read/write memory) as a SixPakPlus.

Extra memory is really what the Advantage! is all about. The board's minimum memory configuration is 128K bytes of RAM, enough to take an enhanced IBM PC AT with 512K bytes of memory up to the machine's lower limit of 640K bytes. (The PC AT can use 640K bytes of RAM in its 1-megabyte real-address-mode address space.)

But the IBM PC AT doesn't stop there, and neither does the Advantage! multifunction board. Using the AT's protected-mode memory configuration, Advantage! can contain up to 1.5 megabytes of RAM. This is extended RAM that resides above the normal 1 megabyte of real-address-mode memory-address space that the AT uses for routine operation. You can use this protected-mode memory space for RAM disks such as the IBM PC-DOS 3.0 VDISK utility or for multiuser operating systems like IBM's XENIX package.

If that isn't enough RAM for your needs, Advantage! accommodates a special piggyback memory module that attaches to the board itself and extends the total on-board memory to 3 megabytes. This means that you can add a full 3 megabytes of RAM to your IBM PC AT while using a single expansion slot. Cascading more Advantage! boards, up to a maximum of five, results in 15 megabytes of protected-mode memory (the maximum the machine will accept). Furthermore, Advantage! offers several other memory-expansion options to meet your goal. You can choose either 64K-bit or 256K-bit RAM chips for maximum flexibility when upgrading your system's memory.

MEMORY-ADDRESSING CAPABILITY

Memory addressing, the function of Advantage! that designates where extra memory appears in the machine's address space, is also flexible. The total on-board memory can be split to fill space in both the base (real-address-mode) memory system and the protected-mode memory area.

In other words, if your AT has 256K bytes of base memory and you add a 1.5-megabyte Advantage! board to your system, you can choose to put all 1.5 megabytes in the protected-memory area and leave the base memory alone. This decision results in a machine with 256K bytes of base RAM and 1.5 megabytes of extended memory for use as a RAM disk or for multiuser functions.

Or you can split the extra memory between the two modes. Through the use of DIP (dual in-line package) switches, you can fully load the base memory by sectioning off 384K bytes of the 1.5 megabytes for use as base memory. The maximum base RAM is 640K bytes of the assigned 1-megabyte address space (in this case, 256K original bytes plus 384K bytes added by addressing the Advantage! board). This leaves 1116K bytes, or 1.116 megabytes, for use as protected-mode memory.

COMMUNICATIONS PORTS

The Advantage! multifunction board also contains a serial communications port and

(continued)

TJ Byers is the author of numerous books and articles on computers. His latest book is Inside the IBM PC AT *(McGraw-Hill). You can contact him at 9411 Soledad Canyon Rd., Canyon Country, CA 91351.*

AT A GLANCE

Name
Advantage!

Company
AST Research Inc.
2121 Alton Ave.
Irvine, CA 92714
(714) 863-1333

Computer
IBM PC AT

Features
Memory expandable to 1.5 megabytes on-board, memory expandable to 3 megabytes on-board with piggyback module; split memory-addressing capability; uses 64K- or 256K-bit memory chips; parallel printer port, serial RS-232C asynchronous port, and optional second serial port and game port

Documentation
75-page user's manual, tabbed function identification

Price

128K bytes of memory and serial/parallel ports	$595
3 megabytes of memory with piggyback board and serial/parallel ports	$2395

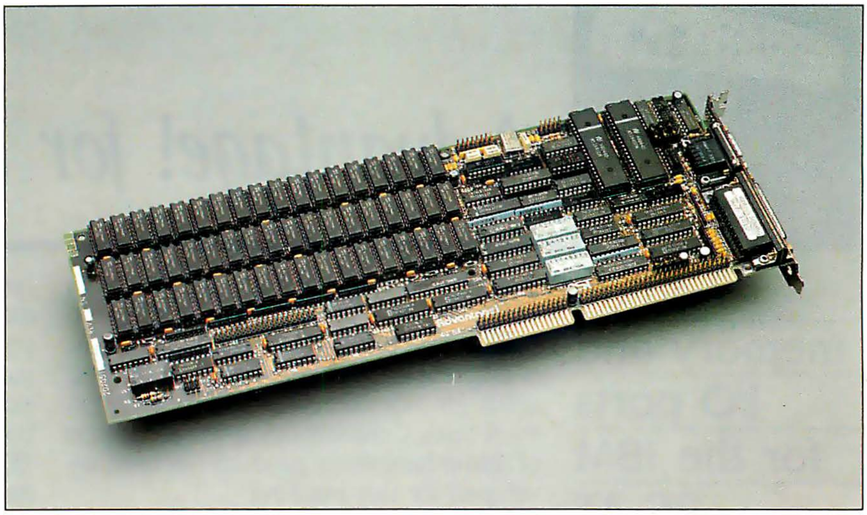


Photo 1: *The* AST *Advantage! multifunction board for the* IBM PC AT, *showing sockets for up to* 1.5 *megabytes of* RAM, *memory-address* DIP *switches, and parallel-port, serial-port, and game-port connectors. Note the rows of vertical pins in front of the* RAM *socket area and immediately above the printed-circuit fingers; these are for connecting the optional add-on* 1.5*-megabyte piggyback* RAM *board.*

a parallel communications port. The serial port is an RS-232C–compatible asynchronous communications port that you can use to provide a link between the AT and a modem, serial printer, mouse, or other serial device. Unlike on the IBM PC, which uses the industry-standard 25-pin DB-25 connector, Advantage!'s RS-232C port is interfaced via the 9-pin DB-9 connector that IBM is using as its new RS-232C standard. A second asynchronous serial port is offered as an option.

The parallel printer port is also standard on the Advantage! board. It performs exactly like any IBM parallel printer port, such as the one that comes on the IBM monochrome monitor, and can be used in conjunction with the AT's existing parallel port. The IBM PC AT can support three parallel ports, and you can configure Advantage! to respond to two of the three assigned addresses.

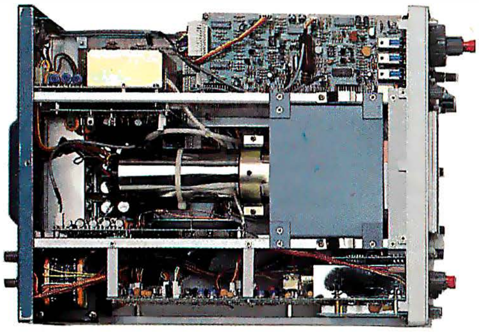
As a final option, you can install a game port. The game port is totally software-compatible with the IBM game adapter and you can use it with most joysticks. Due to a problem in the diagnostic program that accompanied some of the earlier AT machines, the port might not always show up on the listing of installed devices. This causes no problem in the use of the game port, so ignore it.

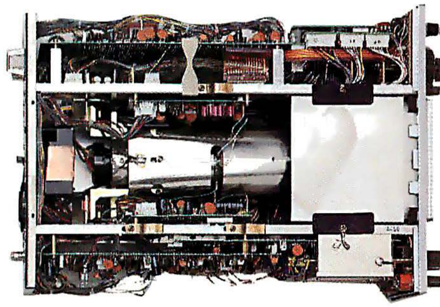
DOCUMENTATION

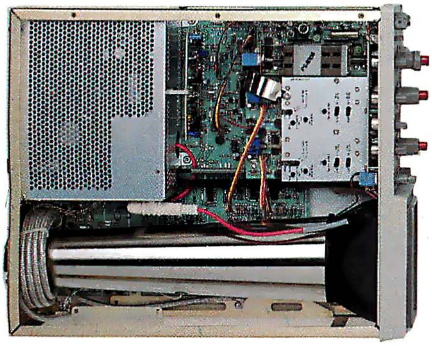
Probably Advantage!'s best feature is its documentation. It is clear, concise, and to the point. AST has broken down the operation of each function into a separate and extremely manageable chapter. The text is not overwhelming and the manual is well illustrated. The user's manual includes four appendixes that contain all possible switch settings and actual programs to modify or improve system performance. This is a welcome and noticeable improvement over some manuals I have used.

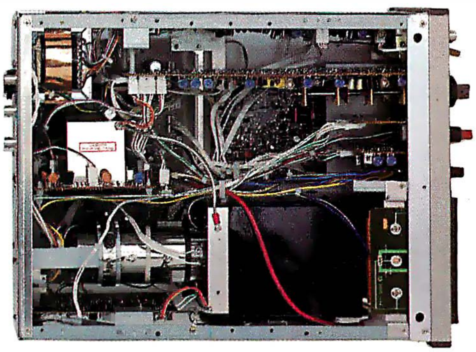
Priced at $595, Advantage! is a good buy with plenty of capability. Of course, prices increase as the number of memory chips you use increases, but that's to be expected. Advantage! lives up to everything it promises. I have used the Advantage! board for RAM disks and as extended memory with the XENIX operating system, and the results have been excellent. I highly recommend it for the serious AT user. ■

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Enable

Powerful, but not quite ready and able

BY STEVE KING

Enable, a $695 integrated software package from The Software Group, would appear to be ideal for certain applications on the IBM Personal Computer. Imagine, for example, writing a guide to restaurants and restrooms in your area. You could use Enable's word processor to write the text for the guide, its database manager to assemble the data, its spreadsheet to track the associated expenses and income of the project, and its communications module to transmit the finished manuscript to the typesetter. Throughout the project, Enable's window-management capabilities would apparently let you easily keep an eye on all these functions. You could even use Enable to prepare some charts and insert these into the text.

Unfortunately, an actual test of the software with such a project revealed several deficiencies in Enable. Of course, I used version 1.0. After I wrote this article, The Software Group released Enable 1.1, which is said to include some enhancements. No doubt this new version will fix many of the deficiencies I found. In the meantime, I will report on the software as I, and perhaps many customers, received it. [*Editor's note: The new version of Enable does indeed fix many of these deficiencies. See the text box "Enable 1.1" on page 334 for some notes on the new version.*]

Enable 1.0 comes on three disks: a system disk, an operation disk, and a tutorial/data disk (the new version comes on four disks). I evaluated the program with a Compaq Deskpro containing 640K bytes of RAM (random-access read/write memory) and two floppy-disk drives. Since Enable requires frequent disk swapping on a floppy-disk system, I recommend using a hard disk. By the time I finished this review, I was quite burned out by Enable, partially because of so much disk swapping. Not only do the program's many overlay files require frequent disk changes, but The Software Group also employs a copy-protection scheme that checks drive A occasionally to verify the presence of a bona fide system disk, even if you're running Enable from a hard disk. Fortunately, the new version of Enable is not copy-protected.

Enable's maintenance plan, which includes toll-free telephone support and free updates for a period of one year, costs $95.

In addition to a spiral-bound manual for each of its five modules (word processor, spreadsheet, database manager, communications, and overall system control), a getting-started booklet, a quick-reference guide, and a small binder of helpful hints, Enable comes with a large keyboard overlay that gives the word-processing and telecommunications commands on one side and the spreadsheet and database-management commands on the other. The Software Group has written all the documentation as a tutorial, which makes it difficult when you just want to look up something, even though the manuals contain extensive indexes.

INTEGRATION AND CONTROL

When you first start Enable, you proceed through a series of menus to your desired function. The software creates a border that displays messages. This border limits the display to a 78-column width.

Enable boots into the Master Control Module (MCM), which integrates Enable's functions. The MCM also controls windowing, file handling, extensive macro capabilities, and a profile of the hardware in your system.

The MCM duplicates most of the operating-system file-manipulation commands. The module lets you select, copy, rename, and erase files from a single menu. However, the MCM doesn't display files that were not created by Enable. The MCM also prevents you from accidentally erasing Enable's system files.

After you choose a profile, the MCM lets you select one of the four applications modules: word processing, spreadsheet/graphics, telecommunications (Telecom),

(continued)

Steve King is a program analyst for the state of California and a part-time writer and consultant. When not working with computers, he enjoys equestrian activities. He can be reached at 17625 Rancho de Oro, Ramona, CA 92065.

AT A GLANCE

Name
Enable 1.0

Type
Integrated software package

Company
The Software Group
Northway 10, Executive Park
Ballston Lake, NY 12019
(518) 877-8600

Format
Three 5¼-inch double-sided floppy disks, MS-DOS 2.0 format

Computer
IBM PC or compatible with at least 256K bytes of memory and two floppy-disk drives; hard-disk drive suggested

Features
Word processing, spreadsheet, database management, graphics, windows, macros, communications, context-sensitive help

Documentation
Five 7- by 9-inch spiral-bound manuals, approximately 150 pages each, three pamphlets, and one keyboard overlay

Price
$695

and database-management system (DBMS)/graphics. Then it helps you choose the file you wish to process. If you don't remember a file's name, enter a question mark and the MCM takes you to the file-control menu. To select the file you want, move the cursor to it and press the enter key.

The Software Group gave Enable's MCM impressive macro capabilities (the ability to execute stored keystroke sequences, including data entry and commands). You can tell Enable to record keystrokes for playback later or, once you have learned Enable's macro language, you can create macro files with the word processor. The Enable disks contain extensive tutorials that impressively demonstrate use of the macro powers.

WORD PROCESSING

I tried Enable's word-processing function first and it almost soured me on the rest of the program. When the word processor starts up, you must set your document margins each time you start a new file.

Next, Enable assumes you want a title page for every new document you create. However, you can move the cursor down past the title page and start entering your text. You can also type the key sequence F9-O-N-T to delete the title page.

The series of keystrokes necessary to delete the title page typifies one of Enable's big problems: In general, the commands are too complicated and require too much moving about the keyboard for easy learning. For example, F2 with the up-arrow and P keys takes you to the beginning of a paragraph; F2-P takes you to the end. Most cursor commands start with F2; most text-manipulation commands begin with F9.

You can also access most text-manipulation commands from a series of menus that the software displays at the top of the screen when you press F10. Since you can't access all commands (such as the title-page command) from the menus, you must frequently refer to the keyboard overlay or the manuals. The overlay is printed in very small type and contains rather cryptic explanations. It was frequently difficult to locate the keystroke sequence I wanted. Usually I resorted to thumbing the pages of the quick-reference guide.

Since the menu command sequences are not similar to the keyboard command sequences, the menus do not help you learn the keyboard commands. In fact, I found that this dissimilarity impeded my learning process. For example, when inserting a page break from the menus, you press F10-L-4; when using keyboard commands, you press F9-Ins-M-P. The Software Group should take a lesson from Mark of the Unicorn and use the same keystroke sequence for menu and keyboard command entry. Mark of the Unicorn's The Final Word brings up a menu if you pause after the command-initializing keystroke or lets you enter the command uninterrupted if you know the correct keystroke sequence.

Despite its clumsy, confusing command structure, the Enable word processor contains almost the same capabilities you'd find in The Final Word, WordPerfect, or WordStar 2000. This program can create headers and footers, tables of contents, indexes, and footnotes. The Enable word processor also has a mail-merge function and can perform extensive boilerplate text manipulation using MCM macros.

However, I had several reformatting problems when I edited my text. The program refused to move a small block of words from one place on a line to another place on that same line.

Sometimes when I deleted or moved a block of text, the software left two spaces in the place from which the block came. Since I couldn't persuade Enable to delete either of the spaces, I was left with two spaces between the remaining words.

If I inserted words into the middle of a sentence, thus forcing the end-of-sentence mark (usually a period) and the two spaces before the next sentence to wrap to the next line, the software dropped one of the two spaces. I had to manually reinsert

(continued)

Want to hear a demonstration of Hewlett-Packard's ThinkJet Printer?

another space to maintain the proper distance between sentences.

The word processor uses its own format for storing files on disks, but it can also store files in ASCII, Volkswriter, EasyWriter, and WordStar file formats. Enable is also supposed to be able to read those other formats. However, when I tried to get Enable to read the BYTE standard word-processor benchmark file, a 40-paragraph ASCII file, it would read only the first line. I used a public-domain utility to convert the benchmark file to WordStar format, but the Enable word processor still would read only the first paragraph of that format.

ENABLE 1.1

BY RICH MALLOY

The new version of Enable corrects many, but not all, of the deficiencies reported by Steve King.

Enable now comes on four floppy disks (utility, system, operation, and tutorial/data) that you must frequently swap in and out of disk drive A. All the disks are copyable, but an Install routine mentioned in the manual does not seem to work. Also, the disk-swap prompt is an irritating sound.

The new word processor can now handle text lines longer than 78 columns (up to approximately 160 columns). To help you set margins, a small window in the screen's lower right corner indicates which column the cursor is in. Also, if a reformatting operation leaves an extra space between words, you can delete the extra space with the Del key. You can turn off the automatic creation of a title page for each new document by changing your system profile. Finally, Enable can read ASCII files fairly easily.

The database manager can now easily merge data files.

The updated spreadsheet offers variable formats from 256 rows by 256 columns to 4095 rows by 15 columns. The spreadsheet can also easily read and recalculate Lotus 1-2-3 worksheets.

The telecommunications module now lets you set up a wide range of communications parameters. It also can do simple auto-log-on procedures. However, this module still has a few simple problems. For example, it stores your desired parameters on the utility disk, but the operation disk looks for these parameters on your data disk.

Some items were not mentioned by Steve King. Enable does not currently support printers made by Star Micronics, C. Itoh, or Mannesmann Tally. No provision lets you modify Enable for additional unsupported printers. When I set up Enable for an Epson MX-80, connected an IBM PC to a Star Micronics Gemini printer, and told the system to print, it locked up irretrievably.

The word processor seems to contain other shortcomings. Copying a block of text seems to cause some paragraph indentation in the block to be lost. And for some reason, the backspace key functions as a reverse space bar; it blanks out the character to the left but does not delete the space. You can change this to a normal backspace function by adjusting your system profile, but the backspace key sometimes reverts to its default behavior for no apparent reason.

Finally, in the system-profile section, you apparently cannot change that part of your system profile that refers to your modem.

After a brief test, I would judge the updated product to be much closer to its advertised claims than the version used by Steve King. Note that because of the extensive disk swapping required, I would discourage Enable's use on floppy-disk systems. Also, like Mr. King, I would have preferred that the publisher had made Enable's menu and command sequences identical. Finally, some procedures, such as Install and the one to set up a particular modem, do not seem to work.

All in all, on a hard-disk system and for certain applications requiring several different functions, Enable appears to be a viable, if somewhat idiosyncratic, product.

Rich Malloy is the New York editor for BYTE. *He can be reached at* BYTE, *McGraw-Hill, 43rd Floor, 1221 Avenue of the Americas, New York, NY 10020.*

DATABASE MANAGEMENT

Of Enable's functions, I found the database-management system and the spreadsheet to be the most logical and the easiest to use. The DBMS module contains almost all the capabilities of popular middleweight database managers such as dBASE II or Condor 3. However, Enable allows the use of, but not yet the merging of, multiple data files. Although the Enable DBMS module doesn't contain a built-in programming language, as dBASE II and Condor 3 do, the MCM's macro capabilities combined with Enable's report language let you design sophisticated data-management programs, such as general ledgers or inventory-control modules.

The Enable DBMS can read dBASE II data files directly. Since The Software Group also provides a utility program, Convert, that translates ASCII-format data files to Enable format, the Enable DBMS can use files created by almost any other database program. I imported a 1260-record mailing list into Enable that Condor 3 had created. I simply told Condor 3 to store the file with fixed-length fields in ASCII format and then used Convert to finish the conversion process.

Each record in an Enable database file can have up to 32 fields (like dBASE II and Condor 3) of entered data or up to 113 fields containing data that is derived or calculated from the entered data. However, each record is limited to 2000 characters.

With Enable, you design a database with a series of menus that lets you specify the type and limits for each field. The software lets you specify an amazing number of details about the limitations for each field, including whether data is entered from the keyboard, derived from another database or from another field, or copied from the operating system.

Next, Enable helps you design the data-entry forms for each database.

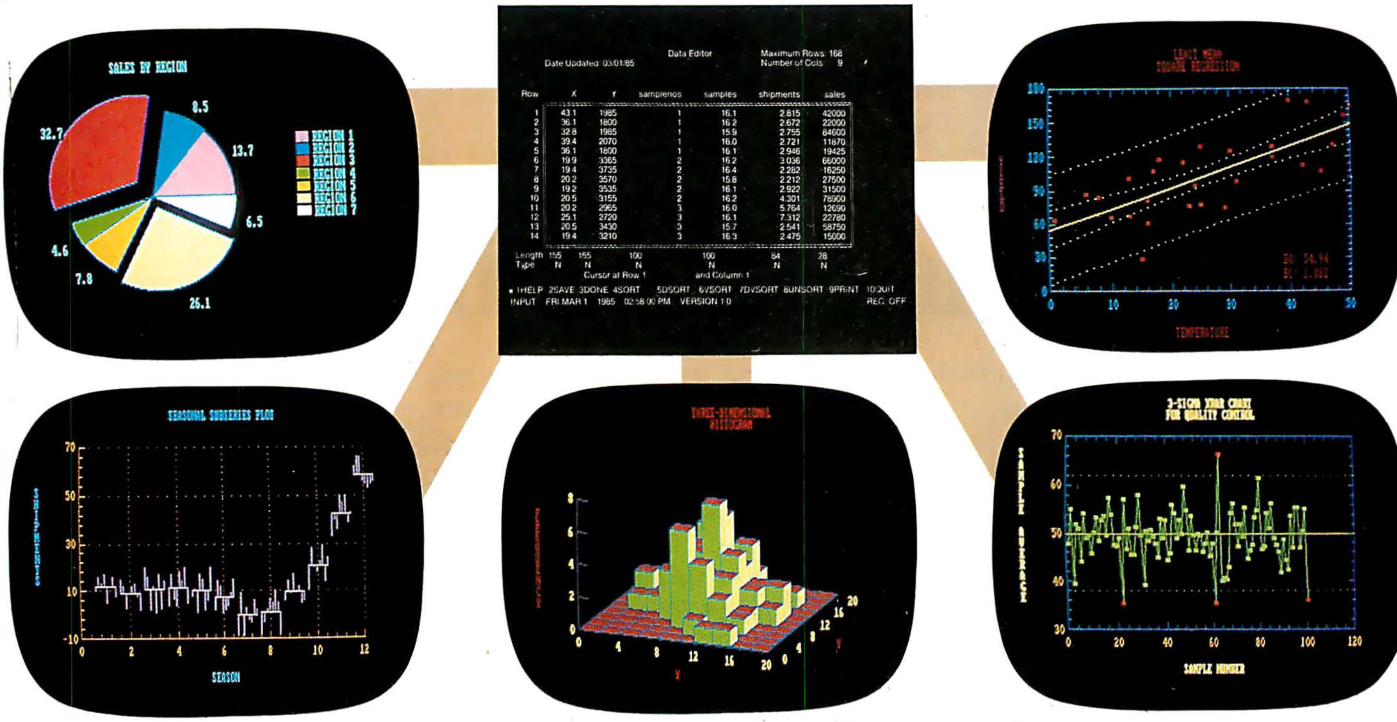
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REVIEW: ENABLE

While designing an entry form, you can access the word-processing module to add text enhancements that give instructions to the data-entry person. You can also specify a verification method that requires entering a particular field twice when accuracy is important.

Finally, the DBMS module lets you design reports in almost the exact way that you design data-entry forms. However, The Software Group also has included a rudimentary programming language for creating reports in Enable. Using the word processor, you can construct a report with a series of dot commands (words preceded by a period, or dot). The report language contains .if, .elseif, .else, .exit, and .endif commands to handle conditional situations.

When you are not designing a new database, you can bypass the DBMS menu and enter direct commands to the software as you do when using the word-processing module. The F9 key initiates these commands but, once again, no relationship exists between the menu command sequence and the keyboard command sequence.

SPREADSHEET

Since I don't own Lotus 1-2-3, I borrowed a friend's copy for comparing it to the Enable spreadsheet. Enable's spreadsheet looks like 1-2-3 and has a similar command structure, but it offers a maximum worksheet size of only 255 rows by 255 columns. However, my friend, who is much more of a spreadsheet expert than I am, believes Enable's spreadsheet size is more than adequate for most uses.

Since I normally use the Report Manager spreadsheet from Datamension (Northbrook, Illinois), which allows 256 pages of spreadsheets as well as 256 rows and 256 columns per page, I found both the Enable spreadsheet and 1-2-3 somewhat limiting. Report Manager's third dimension (pages) lets you generate multiple related spreadsheets, such as a budget page for each month of a year.

The Software Group incorporated

(continued)

most typical spreadsheet capabilities in Enable, such as range commands and global formatting. Enable also has many mathematical functions, including business functions (e.g., amortization payments and internal rate of return), scientific functions (e.g., sine and cosine), and logical/conditional functions (e.g., choose, if, true, and false). The Enable 1.0 spreadsheet can also save files in 1-2-3, VisiCalc, and DIF formats, but strangely enough cannot read files in those formats.

GRAPHING

Both the database and spreadsheet modules let you design graphics images on the video screen if your PC has graphics capabilities.

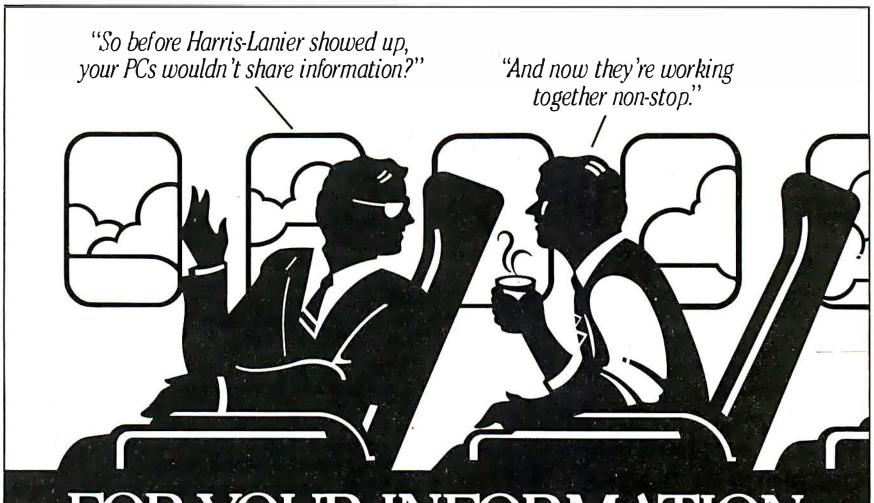
Enable can create vertical bar graphs in two and three dimensions, as well as pie charts and line graphs. I found Enable's graphs much easier to format and print than those created by 1-2-3, Report Manager, and Condor Graf. You can design various levels of titles for graphs and embellish them with nine different fonts.

TELECOMMUNICATIONS

Enable's telecommunications module is its weakest point. It requires even more disk swapping than the others and has some severe bugs. For example, after you choose Telecom from the main MCM menu, Enable lets you select Communicate or Setup. Setup supposedly lets you change communications parameters. When I tried to use Setup, however, the program beeped repeatedly and instructed me to insert the tutorial/data disk. Enable never accepted the disk asked for and, thus, never let me change the communications setup.

I did manage to convince Enable to communicate by using the Communicate selection to access the program's terminal mode. I called a bulletin-board system and tried to download a public-domain program using the XMODEM error-checking protocol. Unfortunately, after you tell Enable to receive a file using XMODEM, the program prompts you to swap a disk before it begins to receive the file.

(continued)



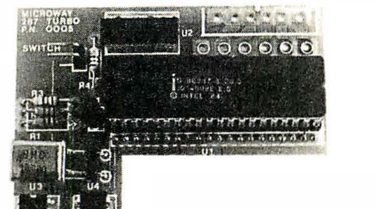
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After it has received the file, Enable prompts you for another disk swap before it returns to the terminal mode.

After three attempts, the public-domain program I downloaded would not run. Yet, when I downloaded the same program with another communications package, the public-domain software worked properly.

A TEST

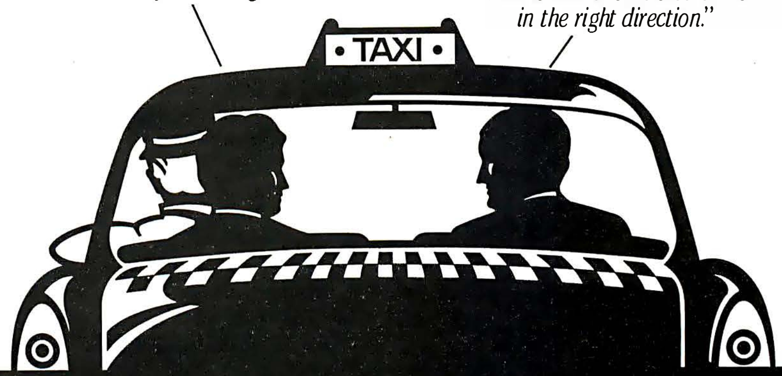
To put Enable to a good test, I used a data-entry-and-report form that my coworkers and I designed for collecting restaurant and restroom data in our area for use in a "restaurant and restroom survival manual." I originally designed two similar databases, one for restaurants and one for restrooms. But after some experimenting, I learned that the menu command allowing the merging of two databases was not yet implemented. So, I entered both types of facilities into a single database, using a true/false conditional field to differentiate between a restaurant and a restroom.

Next, I spent about 12 hours entering the data for the survival manual. Then I used the Enable word processor for several more hours to write a witty preface. Finally, with the Enable word-processing module running and the preface on the screen, I pressed F10 to access the program's command menu. It offered me a number of choices. I chose DBMS to integrate the restaurant and restroom database with my text. That's when Enable told me: "Function will be available in first Enable update."

Of course, maybe it was my own fault. I hadn't read anything about using that particular menu command in any of the manuals. Fortunately, the documentation did offer another method for combining the two files.

Following the manual's instructions, I rebooted the word processor with the preface text. With the MCM, I switched windows and ran the database module. I used the display command to access my database. It showed the database on the screen with each record occupying one line. However, if a database were to con-

(continued)



REVIEW: ENABLE

tain more than 78 characters per record, the program would let you scroll as far right as necessary to view the entire record, similar to a spreadsheet. Since my database contained two comment fields (for directions and comments) of 127 characters each, my records scrolled a long way to the right of the screen window.

Still following instructions, I marked the whole database as a block and returned to the word-processing window. I told Enable to move the block into my text. The program carried out my command, but each record extended to the right beyond the word-processor screen window.

Unfortunately, the word processor could not scroll to the right. When I tried to scroll to the right to look at the results, my PC locked up and I had to reboot and repeat the procedures. Then I tried to reformat the database, but that didn't work either and, after several tries, my computer froze again.

I finally gave up on Enable for the survival-manual project.

SUMMARY

As all reviewers do after completing their projects, I'm returning Enable to BYTE along with this review (needless to say, I did not write it with the Enable word processor). I am totally disenchanted with Enable's awkward, difficult-to-learn command structure and unimplemented features.

Software manufacturers encounter enormous costs and delays as they develop their products. However, I don't believe consumers should be forced to endure bugs and unimplemented features such as I found in Enable 1.0.

Enable is a powerful program and probably the most successful attempt so far at a single software package that integrates the most common uses for microcomputers: word processing, database management, spreadsheets, and communications. Although I've heard version 1.1 is better, I found Enable 1.0 not quite ready and able because it is plagued by bugs, incomplete functions, and a clumsy disk-swapping scheme. ■

TOSHIBA P1340

I have become a bit puzzled about the reviews for printers in BYTE the past year or so, particularly after purchasing a Toshiba P1340 printer.

The review of the Epson LQ-1500 (BYTE, December 1984, page 293) gives a sample of print from the P1340 that was made with a printer that was not working properly (see Maxim Smith's letter in Review Feedback, May 1985, page 299). The same is true of reviews of the IBM Quietwriter (June 1985, page 385) and the P1340 itself (October 1985, page 305). The print samples from the P1340 in all three of these reviews were done with P1340 printers that were not working properly.

When I got my P1340, I was warned that it was common for the flexible cable from the printer body to the print head to work loose, or partly loose, and that I would need to be sure that it was securely connected. Until I did this, my printer did not print properly.

Whatever the cause, the P1340 can (and should) print better than the examples shown in BYTE. Reviews of the P1340 should warn buyers about the possibility of loose cable connection, or whatever causes the problem.

DENNIS P. MCGUIRE
Minneapolis, MN

I want to compliment your review of the Toshiba P1340 printer. I was particularly impressed that the reviewer, Rich Malloy, accurately reported the machine's usable fonts, rather than repeating the erroneous specifications advertised by Toshiba.

It should be emphasized to your readers that this machine does *not* have a usable letter-quality font at 12 characters per inch, despite the fact that Toshiba implies such a font in its advertising and in the user's manual for the P1340. In fact, my experience with Toshiba after purchasing a P1340 suggests a disdain on the part of Toshiba for its customers; this might be of interest to any of your readers contemplating the purchase of a Toshiba printer.

Readers should know that an executive of the company told me that since I had purchased the printer from a discount house, at a below-list price, I had no right to expect Toshiba to accept return of the printer. Had I purchased the machine from an authorized, "full-price" dealer, Toshiba would have accepted a return.

Altogether, my experience with the Toshiba P1340 was very unsatisfactory. That is too bad, because in many respects it is a very nice printer. My advice is to look for a manufacturer that has some regard for its customers and for the integrity of its advertising.

EUGENE H. LEVY
Tucson, AZ

DESKPRO GRAPHICS

In the August 1985 Review Feedback (page 283), Bryan Mumford made a note that the Compaq Deskpro will not run any of the popular graphics cards, such as the Hercules card. This is not quite the case. The monitor supplied with the standard Deskpro will not run on these cards.

When I saw this letter, I went to the local Micro Mart; they assured me that the Deskpro will run these cards. I have seen Deskpros running a Sigma Color Design 400 with a Princeton Graphic Systems SR-12 Monitor. They also claim that they have sold Deskpros with Tecmar Graphics Master cards and several other graphics cards, but not with the Deskpro monitor. One suggestion to Mr. Mumford: See if the Princeton Scan Doubler will work with the Compaq Graphics Adapter; that will give you 640 by 400 resolution on the Compaq monitor.

ANDREW BOWEN
Bethel Park, PA

STEARNS DESKTOP

The review of the Stearns Desktop Computer (October 1985, page 264) by Wayne Rash Jr. mentioned some severe problems without correctly identifying the causes.

Though I left Stearns in May 1985, I was the hotline support specialist who answered Mr. Rash's telephone questions and inspected the Stearns computer after he returned it. The computer he used for the review was in BYTE's possession for over a year and had been visibly damaged in one (or more) of the three (or was it four?) shipments that BYTE arranged for the computer. The unit had been dropped so hard that the hardened plastic case cracked, freeing the case's retaining screws. One of these loose screws lodged under the main computer board (affecting the keyboard interface), a second was found in the power supply, and the third was near the disk controller. When the screws were removed, the keyboard and disk drives functioned perfectly. Few electronic devices function well (if at all) when shorted.

Perhaps, in retrospect, I should have been more insistent about shipping a replacement unit. After all, the first dealer service provided to Mr. Rash was removal of a piece of the plastic case from the interior of the floppy-disk drive. He repeatedly refused my offers to send a unit directly from the factory—an admirable attempt by BYTE to maintain continuity and integrity, but a mistake in this case.

CAROL L. JAHNKE
Bloomington, MN

For the most part, Ms. Jahnke's reply may accurately reflect the condition of the computer when it arrived in the Stearns offices. I did not notice any severe damage to the machine when I had it, but it was shipped twice more after that. I should note, however, that I would have expected the local service representative to bring such damage to my attention during one of his numerous visits. Since the service rep said nothing, I had to assume that the machine was in optimum operating order.

I should also add that Ms. Jahnke was the model of patience and helpfulness during the time I had the computer. I wish that other computer companies would staff their hotlines with people like her.

Finally, let me add that even had the machine operated flawlessly, my findings as to the utility of the machine, its level of compatibility, and the level of documentation would still stand and would still lead me to make the same recommendation as to its desirability.

—Wayne Rash Jr. ■

REVIEW FEEDBACK *is a column of readers' letters. We welcome responses that support or challenge* BYTE *reviews. Send letters to Review Feedback,* BYTE *Publications,* POB 372, *Hancock,* NH 03449. *Name and address must be on all letters.*



Kernel

COMPUTING AT CHAOS MANOR: ONE MINOR PROBLEM
by Jerry Pournelle **349**

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CIRCUIT CELLAR FEEDBACK
conducted by Steve Ciarcia **403**

One minor problem. That's all it was—nothing more. We've all had them. In fact, most of us have them every day. In Jerry's case, however, the one minor problem kept going on and on and on. It just happened to be the day before Friday the 13th. Although it turned out to be a day that Jerry would not care to relive, he did learn some lessons from it and still has the highest praise for what personal computers can do.

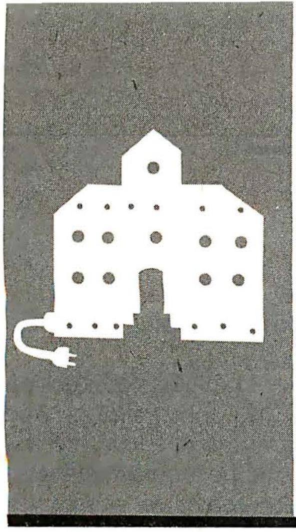
With the big move to Utah finally completed, Bruce Webster feels that he is ready to start working again. This month's According to Webster deals largely with the subject of benchmarks. Bruce discusses what characteristics they should have, how to interpret them, and factors other than performance you should consider. He also makes a number of predictions for 1986 and promises to review them at the end of the year.

This month in BYTE Japan, Bill Raike focuses on the new NEC computers in the PC-9801 series, which no longer have the 8086 but are quite a bit faster. Another new Japanese product that Bill reports on is the long-awaited Japanese-language version of the Macintosh and some software that comes with it. It is the result of the linkup between Apple and Canon and is actually a kanji-character ROM board that's been piggybacked onto the main board of a 512K-byte Macintosh. Finally, Bill discusses the Fujitsu lap-size portable computer that he reported on in last August's BYTE Japan. It is now called the FM-16π and is available at very reasonable prices, but only in Japan.

The events leading to the development of the Acorn RISC Machine, or ARM, is the topic of BYTE U.K. Dick Pountain covers the background provided by previous Acorn machines and describes the goals of the design team and how they were implemented in this RISC processor.

In Mathematical Recreations, Bob Kurosaka returns to the subject of repeating decimals, covered in his November column. That column concluded with an algorithm for converting repeating decimals into fractions. This month's column presents a program to implement that algorithm.

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C·O·M·P·U·T·I·N·G AT C·H·A·O·S M·A·N·O·R

One Minor Problem

Nearly Friday the 13th

Reflections

SpaceWar

Bridge Parlor

Nemesis

MandelZoom

Cardiovascular Program

PC-Sweep

FUPROLOK

Copy II PC Option Board

Hacker Ethic

BY JERRY POURNELLE

Jerry Pournelle holds a doctorate in psychology and is a science-fiction writer who also earns a comfortable living writing about computers present and future.

I've been back from Europe for nearly a month, during which time I've answered 532 letters, thrown out 11 9-gallon trash bags of paper, and caught the flu. Withal, things have almost settled to normalcy. The construction is finished, *most* of the archaeological layers of mail have been answered, many of my books have been taken from boxes and shelved, and some of the great software inflow has been organized. I've even had time to work on a novel. On the other hand . . .

DAY OF THE LOCUST

It was *not* Friday the 13th. It was the day before.

It all started when Mrs. Pournelle made a weekend visit to Seattle. She took along Percy, the NEC PC-8201 lapboard portable. On the way back, she wrote a chapter for her new book and naturally wanted it transferred over to her machine, which happens to be the Zenith Z-150.

"No problem," said I. Little did I know.

Our usual method for transferring Percy's files is to use an RS-232C cable to connect him up to a port on the Golem, our big CompuPro 286/Z80 S-100 Dual Processor. The Golem now reliably runs Concurrent DOS 4.0 and can read and write to a lot of different disk formats: 8-inch and 5¼-inch as well as CP/M and MS-DOS. More on this later.

There is a minor problem: I don't yet have the proper Concurrent DOS software to transfer files in through the Golem's serial ports. Real Soon Now, they tell me. Meanwhile, it is only a minor problem. The Golem boots Concurrent DOS off the hard disk, but he first looks to see if there's a floppy in the top 8-inch drive. If there is, he boots that, which means I can bring him up in old-fashioned CP/M-86, and *that's* not only as solid as a rock but has all the usual CP/M capability for using PIP to transfer files in and out of serial ports. I can bring in files and stash them on the hard disk or in the memory drive, open the 8-inch drive door, press Reset, and everything's fine.

Well, there is another minor problem. The Golem has two terminals: our ancient (and extremely reliable) TeleVideo 950 and CompuPro's PC Video board, which is designed to make an S-100 system capable of running a fair number of MS-DOS programs under Concurrent DOS. The PC Video board naturally wants an IBM-PCompatible keyboard. We've been testing the Enigma 9000, which is a very good keyboard indeed, but it has an interesting feature: when you first turn on the machine, the keyboard squeals and howls until it gets a signal to shut up. This is fine if I'm booting Concurrent DOS, but when I boot with CP/M, nothing ever talks to that keyboard, so it's going to howl until doomsday, and that's irritating.

"No problem," I say, reaching behind the Golem to unplug the silly thing. My wife, who thinks computers don't like her even though she has made a truce with the Z-150 and actually likes the PC-8201 a lot, waited expectantly for her text. "Hmm," I said. "It doesn't seem to be booting. Maybe a bad boot disk."

I removed the 8-inch disk and hit Reset to let the Golem boot up with Concurrent DOS. Nothing. "Oh. I have to plug that keyboard back in." I did. Reset. Nothing.

"Do we panic yet?" Roberta asked.

"Yes." Actually, what I did was call Tony Pietsch. When Reset does nothing, you have a real problem.

He listened to the symptoms. "Don't know. That's hardware, all right. Have you done the usual? Check the fan filter? Take the cover off and push the boards in? Check the cable connections?"

"Uh, yeah," I said somewhat sheepishly. I hadn't told him about removing and replacing the keyboard cable. I managed to get off the line. Sure enough, the hard-disk cable connector next to the keyboard input socket had been partially displaced; it took about one second to fix that, after which everything worked fine.

(continued)

Well, there was a minor problem. The Golem has a *lot* of RS-232C connectors on the back. Concurrent DOS can support four physical terminals. The next hardware development here is to link the Golem with Zeke, the CompuPro Z80 I'm writing this with. I can also simultaneously connect up several different printers and under Concurrent DOS simply say PRINTER NEC or PRINTER HP, after which the Golem knows which port and printer protocol to use. That's necessary. The HP LaserJet is a fine printer for nearly everything, but it can't handle fanfold. Once a month I call in my accounting program, make journal entries for all the checks, and voilà!, I'm done with all that until next tax time; but, of course, the check-writing program expects the checks to be on fanfold paper.

Anyway, there are many cable connectors, and, alas, while each of those connectors has a label, I have never written down which one is the TTY port under CP/M-86. I mean, I've done this 20 times, right? It's obvious, right? Wrong. And indeed, I *did* write it down about a year ago in a logbook. Unfortunately, I never got around to indexing the log. Oh well, it's easier to experiment with different places to plug in than to search through that log. It's a simple experiment. Just put the PC-8201 in Terminal mode and enter STAT CON: = TTY:. When you get things plugged in in the right place, Percy controls the Golem and all's well.

Of course, there is a minor problem. You have to be sure Percy and the Golem's TTY port are set for the same baud rate. The PC-8201 is set for 9600 baud. I don't remember what baud rate we set for the TTY port under the old CP/M 2.2 BIOS (basic input/output system), but it doesn't matter. Changing the Golem's baud rate is simple. Just type Baud 06 9600 (port 6 is the TTY port). Of course, if the baud rate is wrong, you can't change it if you've already assigned the console to the TTY port. The machine's not listening to anything except the TTY port, and it won't hear anything coming in at the wrong baud rate. . . Reset takes care of that. Now change the baud rate, then use STAT, and plug the cable in . . .

After about 15 minutes of mucking about, I had *that* taken care of. The cable was connected, Percy and the Golem were on the same wavelength, and we were ready to send over Roberta's file.

There was one minor problem.

The simplest way to bring a file into a CP/M system from a port is to use PIP. True, if the file is larger than 16K bytes, CP/M has to go off and write some directory information at the 16K-byte boundary, but a 286 machine writing to a RAM (random-access read/write memory) disk will seldom lose anything, even at 9600 baud; certainly not more than a character or two. There are better ways for transferring important data or programs, but for text, PIP is the easy way to go. I invoked PIP.

"Requires Concurrent DOS," responded the Golem.

"Yeah, of course," I muttered. PIP.CMD is for Concurrent DOS. We'd kept the old CP/M 2.2 PIP, but renamed it. Only *what* had we called it? Directory-search time. Sigh. The Golem has a *lot* of files on the hard disk in the A0 area. There's a reason, of course: system files stored on the A: drive, user area 0, can be invoked from any user area of any disk drive. Search away. Eventually I found PIP22.COM, after which it took about 30 seconds to transfer Mrs. Pournelle's file over to the Golem and another 15 seconds to write it from the RAM disk to an 8-inch floppy. No matter what else happened, that file was *safe*. I disconnected the RS-232C cable, removed the CP/M 8-inch boot disk, reconnected the keyboard, and pressed Reset. Concurrent DOS came up fine.

LOOK AT THE DARNED THING

Of course, there were a few housekeeping details.

Now that I had her file in the M: drive, it was no trick at all to change it from the vanilla-ASCII format of the PC-8201 editor to WordStar; that's

(continued)

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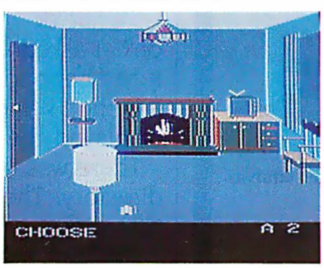
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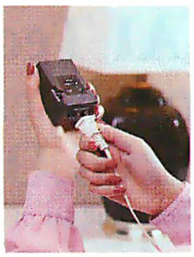
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Inquiry 389

done with Tony's FILTER.COM, a CP/M-80 (Z80) program that comes with the WRITE text editor. FILTER turns WordStar files to WRITE, WRITE to WordStar, and, for good measure, either WRITE or WordStar files to a standard ASCII with carriage return and linefeed at the end of each line (thus suitable for transmission over a modem to BYTEnet or BIX).

It's also *fast*. Even with a normal Z80 it is actually faster to exit WordStar, use FILTER to transform the WordStar file to ASCII, then use it again to put the file back into WordStar than it is to use the WordStar Control-QA global reformat routine; at least it is for files of any size at all. With the Golem's 8-megahertz Z80 slave board, the 286 to do housekeeping, and a RAM disk, it took less than a minute to make both .WS and .TXT transformations of her file. I even brought up WRITE, loaded in the text, and showed her.

"Fine, but how do I get it on my machine?" she asked.

"Nothing to it."

There really is nothing to it. Concurrent DOS on the Golem has a magical property: if I put a DOS disk in the 5¼-inch drive, I can read and write to it just as I would a CP/M disk. Not only does PIP.CMD work, but I can log onto that DOS disk while inside WRITE—which is an 8-bit program running on the Golem's Z80. I need only issue a SAVE on a DOS disk to transfer the file. I didn't do that, but only because it would save it in WRITE format, and she needed WordStar.

"What do you want me to save it on?" I asked. She handed me a disk. It had her book title on the label. I put it in the 5¼-inch drive and from habit displayed the directory.

There was one minor problem. No directory. The Golem wouldn't read that disk.

"Isolate the problem," I said to myself. "Make sure the disk is good. Read it in a DOS machine." I turned on the Kaypro 286i PC AT clone, which is the only fully PCompatible I keep up here.

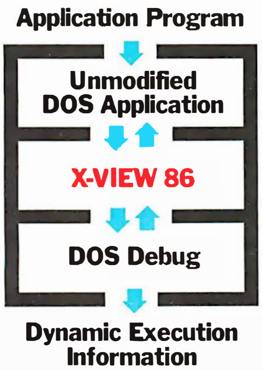
This time there was a major prob-

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lem. It wouldn't boot.

The next few minutes are too painful to describe. Roberta insisted that computers don't like her, while I had a few choice remarks about experimental systems. Of course, I shouldn't have been much surprised by the Kaypro's problem; it had been having progressively more severe difficulties reading the hard disk. To get ahead of the story, it wasn't Kaypro machinery that failed, it was the Seagate hard disk; Kaypro doesn't make hard disks. At the time, though, that was cold comfort, and I still didn't know why the Golem couldn't read Roberta's disk.

"Calm," I kept telling myself. That often helps, although it's probably better not to shout it at the top of your lungs. Why wouldn't the CompuPro read Roberta's disk? Eventually I looked at it. Looked hard. It said: "10 Sector, Single Sided"; it was for her Apple II, not the Z-150. The CompuPro 286 running Concurrent DOS can do a lot of wonderful things, but it won't read a hard-sectored disk.

Eventually we found her real Zenith disks. The Golem had no trouble at all with those, and it took about one minute for PIP to transfer her file. Roberta went away to work, and I went back to answering mail.

The End of the Matter

There was one minor problem. While we were away in Europe, someone had disconnected the monitor from her machine. That one she dealt with, but they had also disconnected her highly portable MPI Sprinter printer, probably to take to a war-games convention. Roberta is at the stage where she'd rather write with a computer than a typewriter, but she also wants paper copies. I understand perfectly: it took me a couple of years before I was able to dispense with paper drafts and work exclusively on screen. She found her printer but wanted help connecting it. I hadn't set it up and couldn't remember if it was serial or parallel.

"Tell you what," I said. "It's getting late. We'll let Alex take care of that tomorrow. Let Don print it on the IBM PC." I went back to the mail...

After a while Roberta was back. Her file is in WordStar. Don Hawthorne, our assistant, was using XyWrite. FILTER on the CompuPro will transform a file from WordStar to XyWrite, but that's an 8-bit program. Don has a genuine IBM PC. If you read an untransformed WordStar file into XyWrite, you see Greek letters, and graphics symbols, and other extraneous matter, all designed to make you think your files have been corrupted and your text lost...

The next few minutes were again too painful to describe. Eventually I convinced her that nothing was lost. Of course, she still didn't have a paper copy.

"Please hook up my printer."

"It's almost suppertime. Here, I'll print it."

She looked a bit wary.

"It's no problem," I assured her. I took her disk upstairs and put it in the Golem's 5¼-inch drive. In seconds I had a copy in the RAM-disk drive. Seconds later I had used FILTER.COM to make a WRITE conversion of her WordStar file. I added commands to put in page numbering and double spacing and to print the date as a footer.

"While I'm at it, I'll make a really safe copy of all this," I said. Hard disks and 5¼-inch disks are all very well, but to me "really safe" means an 8-inch floppy backup. I formatted a disk and put all her files on it. "Now we're ready to print."

Of course, there was one minor problem. Although the Golem can run the HP LaserJet, he generally isn't connected to it; the printer is normally connected to Zeke, the machine I do all my books on. (I explained why I write with an ancient Z80 rather than one of the newer machines in the November 1985 column. Basically, I want *one* machine that no one experiments with.) It wouldn't be much of a problem. Zeke, being a CompuPro, has no trouble at all reading 8-inch disks written by the Golem. I turned the Z80 on.

Zeke is purely a writing machine; there's an autostart program that

brings him up in WRITE. Zeke trundled for a moment, then was quiet. I looked at the screen. "Memory Error at CF61. Exiting WRITE."

I stared at that message. WRITE has a built-in memory-test routine, but I had *never* seen any result from it before. I pushed Reset. Same result. "Memory Error at CF61."

"Is it time to panic?" Roberta asked.

"I *will* keep calm," I kept saying, but in truth it was close to panic time; any other machine can fail without disastrous consequence, but Zeke is absolutely vital. "Logic," I told myself. Check the fan filter. Shake the cables. Open the box and push the boards in properly. Turn on the machine again. "Memory Error at CF61. Exiting WRITE."

"Now it's time to panic."

Fortunately, early training prevailed. In the old days—prior to 1981—computers were *expected* to glitch. Zeke was from that era. When Tony built the machine, he insisted that I buy spare boards. Zeke proved so reliable I'd never needed them, but in fact I have enough boards to build a new computer.

Locating them wasn't easy, but eventually I found a CompuPro RAM-17 64K-byte memory board. Blow the dust off the box. Take out the board. Now pull out Zeke's memory board. Study the switch settings. This should be simple . . .

There was one minor problem. The phone rang. When I got rid of the caller, I realized I didn't know which of those two identical boards had come out of Zeke and which was the spare. Worse, they had different switch settings, and of course the bad board was the one with the switches set the right way. Now which was which? I put in a board and turned on Zeke. It was downright comforting to see "Memory Error at CF61. Exiting WRITE."

Five minutes later Zeke was working fine, and five minutes after that Roberta had her paper copies. The day before Friday the 13th was over.

REFLECTIONS

I wouldn't want to repeat that day, but it did have its useful aspects.

First lesson: I've been spoiled. When I first began writing with computers, I bought a modular system because I *expected* glitches. In the old days, I would *always* push in boards, shake cables, and generally muck about looking for obvious problems. If that didn't work, I'd systematically replace boards.

No longer. For five years Zeke has been on 8 to 12 hours a day, seven days a week, with time off only when I take trips; and in that time I have replaced one disk drive (the heads got out of line and began eating disks) and done one general housecleaning after moving the machine from one

(continued)

room to another; now I've had one memory-failure error. Except for the time the drive went bad, I haven't even had (8-inch) *disks* fail. No wonder I was lulled into a false sense of security! But I should have remembered what to do.

Second lesson: don't put the computer memoranda into the day book. Keep a *computer* log, and log *everything*. Baud rates. Port numbers. Cookbook instructions on how to do stuff that's important but infrequently needed. I always kept a complete computer log in the old days. It doesn't cost much. My local drugstore sells those mottled black-cover composition books for $1.89—never mind that when I bought my first computer the same book cost 45 cents—and it's plenty easy to keep one in the bookcase next to the machinery.

Third lesson: years ago I concluded that "the best business microcomputer is a year-old development system." It no longer makes sense to talk about "the best business micro." Too much depends on business needs and the software base. Even so, there's a bit of truth to the maxim. The Golem is an advanced experimental development system. Viasyn (CompuPro) still dominates the development-system market, and Dr. Godbout is forever sending down new refinements; but the heart of that modular S-100 system doesn't change, and the machine gets the job done.

I can't say I'm entirely happy with the way CompuPro treats software. I wish mightily they'd take at least one more step toward PCompatibility. Even so, I'm still running all the 8-bit programs I wrote and refined and tailored to my needs. I've recompiled some in Compiling CBASIC CB-86 so they run even faster. (For all my fascination with Modula-2, my accounting system and most of the business programs I rely on are written in Compiling CBASIC, which is one heck of a good language.) In addition, I can run Lotus 1-2-3 and a number of other PC programs; indeed, with Concurrent DOS I can run Lotus 1-2-3, my accounting program, WRITE, and three other things at the same time. I can read from and write to a dozen disk formats.

Computer users have to make choices. A long time ago I thought I'd made mine: I was going to be a *user*, not a hacker; I wasn't going to learn programming, I didn't care about the innards, I didn't know or want to know one chip from another. In times of stress I talk as if I still thought that way; but in fact that's a silly attitude. Powerful machinery gives me capabilities other people don't have. It also demands that I learn something about how to use it. The trade-off is worthwhile.

Example: in about an hour, Larry Niven and Steve Barnes are coming over to work on *The Legacy of Hereot*, a three-way collaboration. (Actually, it's a collaboration between Larry Niven and Jerry Pournelle, who make up one auctorial entity, and Steve Barnes, who is another; but that's for a different discussion.) The point is that while Niven and I have identical machines, Barnes uses a PCompatible and WordStar 2000. My big CompuPro 286/Z80 will read his disks and transform his text into WRITE files. We'll work for the afternoon, and when we're done, we'll put one copy back into DOS for Barnes and another onto an 8-inch disk for Niven.

Do that with your off-the-shelf PClone.

Development-quality machinery isn't for everyone. Being state of the art has costs. On the other hand, it wasn't the Golem's fault that I shook a cable loose.

When all is said and done, Roberta did manage to write a chapter while on an airplane. We did manage to get it out of the machine and onto paper. I was able to write a column, several chapters of a novel, and a ton of notes while traveling in Europe, and *all* those safely reside on disks. So we had a bad day. We also got things done that a few years ago I'd have thought impossible.

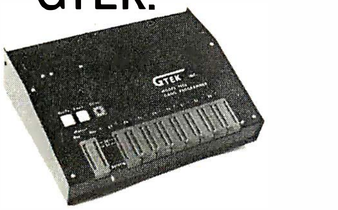
I love these little machines.

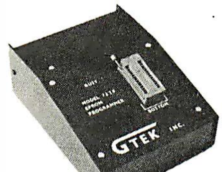
LOOK FIRST

If you are contemplating buying a CompuPro machine—and I like mine

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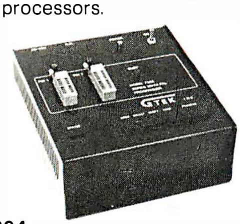
You would think when IBM needs EPROM Programmers they would choose the best and the most expensive. They don't. They only choose the best. GTEK.





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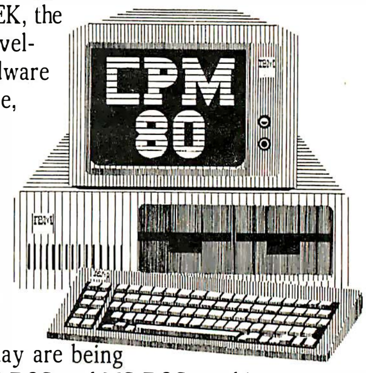
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a lot—you might want to know more about what you're getting into. C-Pro, the independent CompuPro User Group (POB 2146, Woodbridge, VA 22193), publishes an increasingly useful magazine as well as maintaining a bulletin board. There have been a number of debates over software, there are tips about support, and there is enough information to make it well worth subscribing to. If you already have a CompuPro and aren't a member, you're really missing something.

A WHOLE LOT OF STUFF

Every shelf in my office is a potential guilt trip; the place is *crammed* with interesting software. Sigh. Even giving short shrift to each won't get them all mentioned, much less do justice to them. In other words, my apologies: it's that time again, when I race along giving brief mention to programs that deserve a lot more space than they're going to get.

First, there's SpaceWar for the IBM PC. This is a full implementation of the classic game first done at MIT. It can be played by one player or two, with or without star and gravity fields. It has phasers and torpedoes, and the ships move in inertial space, meaning that if you accelerate you'll keep moving in a straight line until you rotate the ship and blast again. It has nearly everything. Great game.

SpaceWar is user-supported software, meaning that you can get a copy from anyone who has one, but you should send the author $20 if you like it and use it.

Next, there's Bridge Parlor, which plays a very good game of bridge; I've been using it to relax after work at night. This one also runs on PCompatibles, including the Kaypro AT clone. It needs 192K bytes of memory, and I do wish the author had been a little fussier in his use of graphics; here and there I have to look closely to see what's going on.

However: Bridge Parlor plays good, standard bridge. Opponents signal. Normal conventions apply. You can set it for defense practice so that you're never declarer, or you can always sit South with those wonderful hands that South always gets in the newspaper bridge columns. It does all this smoothly, fast, and well. Bridge Parlor isn't as nice as finding three congenial people to play bridge with, but it's the next best thing. Recommended.

I mentioned last month that there's no good computer program that can play go. That's still true. However, you can get Nemesis, the *best* go program (as tested in tournaments). If you've any skill at go, it won't ever beat you,

(continued)

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but it does let you practice. If you have never played the game, you can learn using the program; it will ruthlessly exploit dumb mistakes, so that when you graduate from it to a human opponent, you'll be a more interesting player.

Go players are rated in ranks called kyu, with the lowest being best; Bruce Wilcox, inventor of Nemesis (The Go Master), claims this program is at 20 kyu. I haven't played serious go in 10 years; I can beat the program consistently, but I do have to pay attention to what I'm doing. Whether it's worth $75 depends; if you've much interest in go, you'll probably be playing it long after you've tossed out most other computer games. Wilcox claims there will be stronger versions available Real Soon Now.

It's Glorious!

Every now and then we get wonderful, if somewhat specialized, programs to review.

One such is MandelZoom from Token Software. Those of you who read *Scientific American* will recall the August 1985 cover story on the Mandelbrot set, which is said to be quite possibly the most complex set in mathematics. Mark Bolme of Token Software has done a program that will let you play with Mandelbrot sets on your color PCompatible; and it's glorious.

The disk comes complete with cookbook instructions and a setup to let you examine all the stuff from the *Scientific American* article; if you want to know more, go look it up. With MandelZoom you can step back and look at the big picture or zoom in to examine fine structure. I can't imagine a better way to waste an afternoon or two. No color PCompatible is complete without a copy of this; get one and see what I mean.

Looks Great to Me

Cardiovascular Systems and Dynamics by Nils Peterson and Diana Armstrong is another specialized program; if you need this one, you need it bad.

Their introduction states: "Simulation brings to life the dynamics of a physiology laboratory while avoiding the high costs of animal care and modern equipment."

Most of us are disturbed by the cost of medical training; not merely the money costs, but other ones: the psychic or spiritual costs of using animals not only for research but also for student training. I do not care to become bogged down in the intricacies of this debate. I would suppose that there is no one in the world who *prefers* that animals be sacrificed to train students; the debate is over the necessity.

The late C. S. Lewis said once that he imagined a science that would not do to a vegetable what is often done in experiments to human beings. One of the wonders of computers is their ability to simulate things that we really would not want to do in the real world. As micros become both cheaper and more powerful, we may yet realize Lewis's dream.

The Peterson/Armstrong program simulates cardiovascular systems on a PCompatible machine. I'm not competent to determine how accurate the simulation is, but I had an M.D. and a veterinarian look at it, and both were impressed. I'd very much like to see efforts like this succeed.

Take That

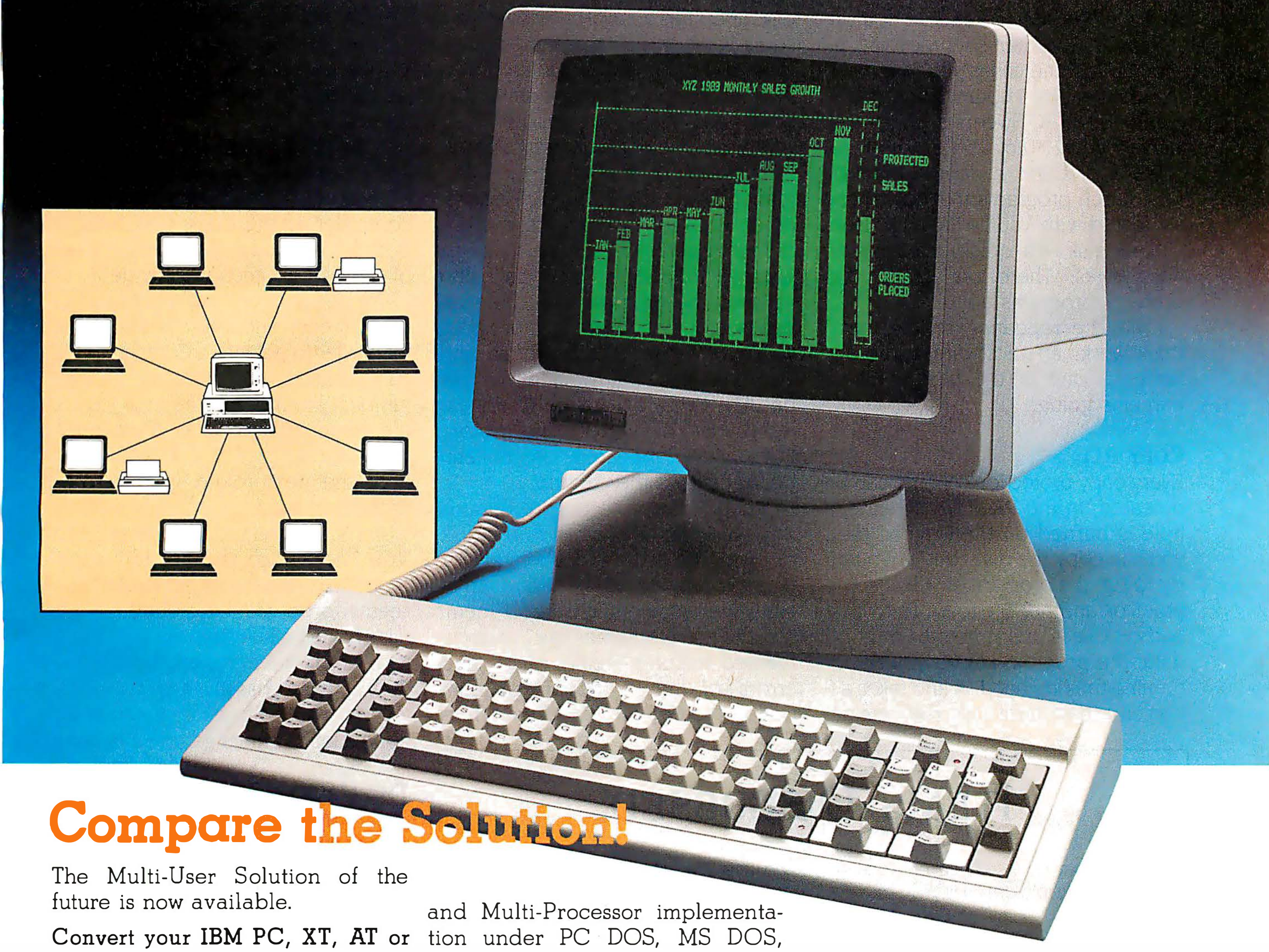
Barry Workman has a new PC disk in his Software Anthology Series. This one contains Sweep for PCompatibles. CP/M Sweep is still one of Workman's most popular items; the new one is from the same authors and works more or less in the same way. With PC-Sweep, you can easily transfer files from one disk or directory area to another, rename, delete, make directories, print files, squeeze and unsqueeze, and a lot more. I use it all the time. Like the original Sweep, PC-Sweep is shareware; if you buy it through Workman, you become a registered user and the authors get their fee.

As usual, the Workman disk contains a mixed bag of shareware, freeware, and public-domain programs.

(continued)

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All have been tested and work more or less as Workman says they will, although in some cases you may need some ingenuity. I count 20 programs on the disk; PC-Sweep is pretty well worth the $32.50 by itself. There's also FUPROLOK.COM, a demon that will let you run programs that have been protected with Vault's PROLOK from a hard disk. It's quick, transparent, and works. There are other "unprotect" programs also.

I may be repeating myself, but I think Workman's Software Anthology Series is one of the best software bargains going.

Copy All

Every copy-protection scheme can be defeated. In the PROLOK scheme, a hole is burned on the original disk; you can copy the disk, but when you try to run the program, it will at some point or another try to write to that bad disk sector; if it gets back good data, the program knows you're not running the original disk and takes action: it either demands the original disk or dumps your program. Indeed, some Vault officials threatened much more drastic action, including the insertion of software time bombs that would damage your computer.

The remedy to this one was obvious from the beginning. Using the information from Crayne's *Serious Assembler* (Baen Books), I was able to write a demon that resides in high memory, watches for the PROLOK call, and satisfies the program that there's a bad sector just where the program wants to see one. I never got around to publishing my demon, largely because I wasn't that sure I'd done it right; but it wasn't long before FUPROLOK appeared on bulletin boards across the country.

Other copy-protection programs rely on doing odd things to the disk format: that is, they deliberately introduce errors onto the disk, then in software try to compensate for them. Most of these schemes use "undocumented features"—really quirks and errors—of the PC floppy-disk controller. The Copy II PC program from Central Point Software will take care of nearly all those schemes. When publishers found that out, they escalated the war.

Central Point's answer to *that* is a new board. You plug it into your PC and connect to your floppy drives, then run the cable from your PC disk controller to the Copy II PC option board. This allows you to defeat most of the new protection schemes.

The option board works fine in a PC, and it's easy enough to install. It's a bit harder to get into a Compaq or PC AT because you have to change jumpers around, but the instructions are clear enough. Once installed it works automatically, and you're set until the next round in the copy-protection wars.

That's one remedy. Another is to Take The Pledge and not buy copy-protected software—a movement that seems to be gaining ground.

It's having results, too. Living Videotext, which makes the excellent Think-Tank program, has given up copy protection. They're to be commended. I hope a lot of others get the message.

The Hacker Ethic

Steve Levy's book *Hackers* discusses "the hacker ethic" of free software. Some of the old MIT free-software people have decided to do something about it. Richard M. Stallman and others have formed the Free Software Foundation (1000 Massachusetts Ave., Cambridge, MA 02138). I don't know all those people, but I've known RMS for some time; and while his views of the world are not mine, I respect his intelligence and his integrity.

They're looking for help. Write and ask for their brochure, and since they don't have much money, slip a buck in the envelope to help them cover the expense of mailing it to you.

Winding Down

It's late, Niven and Barnes are here, and the deadline is due; which is all right, because I am out of space.

The game of the month is still BIX, which takes up more of my time than anything else; but while I was suffering from the flu, I found a strange

Items Discussed

Bridge Parlor . . . Price unavailable
Parlor Software Company
POB 2100
Liverpool, NY 13089

Cardiovascular Systems and Dynamics . . . . . . Price unavailable
Command Applied Technology Inc.
West 400 Main St.
Pullman, WA 99163-0511
(509) 344-6145

Copy II PC Program $39.95
Copy II PC Option Board and Program $95
Central Point Software Inc.
9700 Southwest Capitol Hwy., #100
Portland, OR 97219
(503) 244-5782

MandelZoom $25
Token Software
POB 3746
Bellevue, WA 98009
(206) 455-4130

Nemesis (The Go Master) $75
Bruce Wilcox
34 Oak St.
Lexington, MA 02173

Software Anthology Series
$32.50 per disk, disk 2 of PC Series includes FUPROLOK
WRITE $239
includes FILTER
Workman and Associates
112 Marion Ave.
Pasadena, CA 91106
(818) 796-4401

SpaceWar $20
Bill Seiler
317 Lockwood Lane
Scotts Valley, CA 95066

Wilderness
for Apple II $49.95
Electric Transit
501 Marian St.
Thousand Oaks, CA 91360

Pyramid of Peril has interesting puzzles and a good scenario.

satisfaction in fooling about with the Macintosh version of Wizardry, while the boys continue to play both Gato and Pyramid of Peril on the Mac. Pyramid is really quite nice, with interesting puzzles and a good scenario.

I have somehow managed to neglect Wilderness, an expert-system game developed by Charlie Kohlhase. Charlie's normal job is programming spacecraft; about the time you read this, *Voyager* will get to Uranus using his mission plan. Wilderness is fun and instructional and can teach a lot about living in wilderness areas. Recommended.

The first book of the month is *Klass: How Russians Really Live* by David K. Willis, formerly Moscow bureau chief of the *Christian Science Monitor* (St. Martin's, 1985). Excellent. Example from page 42: "Since I left Moscow, an American personal computer has become the mark of immense klass." If you want to understand life in the Soviet Union, this is the book.

The other book of the month is *Modula-2 Programming* by Ed Knepley and Robert Platt (Reston–Prentice-Hall, 1985); this is a good text for those who already know something of programming and want to learn more about Modula-2.

BIX, meanwhile, continues to improve. I now find myself committed to having a BIX party next month; it was going to be a few friends and now looks to be bigger than that. I hope the place survives. ■

Jerry Pournelle welcomes readers' comments and opinions. Send a self-addressed, stamped envelope to Jerry Pournelle, c/o BYTE Publications, POB 372, Hancock, NH 03449. Please put your address on the letter as well as on the envelope. Due to the high volume of letters, Jerry cannot guarantee a personal reply.

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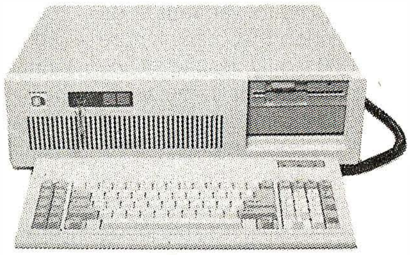
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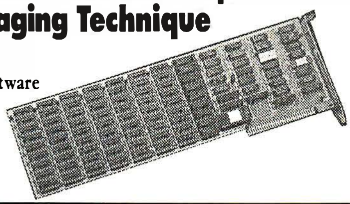
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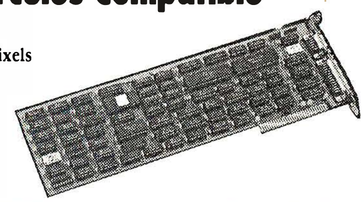
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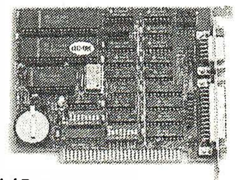
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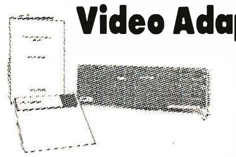
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68000 Objection

Dear Jerry,

In the July BYTE ("Quo Vadimus?" on page 309) you mention that many ignore the Motorola 68000 family despite its fine architecture. For those of us in the scientific world, there is an important reason that 68000-based microcomputers have not yet caught on. That is the lack of a 32-bit floating-point math chip for the 68000 series, analogous to the 8087 family for the 16-bit 8086/8088 series. Motorola has promised such a chip, but it has not yet materialized at the user level. The Skye board, which does do floating-point operations, yields about a factor of 3 increase in speed. A 4.77-MHz 8088-based Compaq with an 8087 will do floating-point calculations approximately 10 times faster than a 68000-based system with a Skye board. The 6-MHz 80286/80287-based IBM PC AT and the 8-MHz 8086/8087-based AT&T 6300 push this ratio to something like 20:1. While 68000-based systems compile and link a lot faster, when you have to start crunching numbers in a language like (I know you hate this) FORTRAN, the next step after Intel's 16-bit series is something like a VAX, which has good floating-point hardware available.

Joel S. Davis
Albuquerque, NM

They tell me that Motorola is fixing this Real Soon Now. Meanwhile, I don't hate FORTRAN; I just don't think there's an easy-to-use implementation of it for micros. Certainly there wasn't back when MacLean and I were first learning about these little machines; FORTRAN was the only higher-level language I'd had any experience with (or read any books about). If there had been a good implementation, I'd probably have been a real champion of RATFOR for micros!

I expect there are good micro FORTRANs now, but I've lost the knack.

Best.—Jerry

Sour Apples

Dear Jerry,

Being a late convert to the world of the microcomputer, I have always been amazed at the biased and bizarre views of so-called computer hackers. I am currently astonished by the childish behavior of hackers who are in reality Apple fans. I continue to read with amusement their immature ramblings on how we all must join with them to save the world from IBM. These California throwbacks to the Aquarian age are so detached from reality that they may never come back. First, let's look at what IBM did. Its people designed a computer using a microcomputer chip (the venerable 8088) from a third-party vendor (Intel), using an operating system from a third-party vendor (Microsoft), and gave out bus and interconnection information so that anybody could design expansion cards and accessories for it. IBM did make some stupid decisions on the monochrome-versus color-display format and that infamous keyboard that opened the door for even more third-party action. But this is hardly Orwell's 1984. Even the most casual perusal of BYTE reveals that numerous small companies are reaping the benefits of what IBM has done.

Now let's look at the Apple Macintosh to see where Apple is headed. Well, it appears that we have a closed system and a proprietary operating system. On top of that, if you want to do program development, you have to sign a licensing agreement that forbids any criticism of Apple (now that sounds like 1984). Look how Apple treated its early Mac supporters by charging them $900 for the memory upgrade to 512K bytes. Contrast that to IBM's decision to send all early PCjr buyers a free replacement keyboard.

Now Apple is trying to call the Mac a business machine. The Macintosh design team was a group of immature computer whiz kids who obviously did not give any thought to creating a business computer. If they did, it's obvious that none of them knew what a business computer is, or should be. Anyone attempting to design a business computer must consider the following basic criteria:

1. Ergonomic keyboard. Since a business requires both text and numerical entries and easy scrolling, you need a good-quality keyboard with a separate numeric keypad and cursor pad.
2. Versatile, clear display: Businesses require the option to use either a monochrome or color display. Since many workers do not have excellent vision, the display must be large (at least 13 inches diagonally) and have excellent resolution. Also, the monochrome and color formats should be the same (sorry, IBM).
3. Two disk drives. A minimum of two disk drives are required to reduce annoying and time-consuming disk swaps and to simplify backing up disks.
4. Built-in expansion slots. Since all businesses have unique requirements, expansion slots must be available to tailor the computer to the needs of the business. To minimize desk clutter and to maximize performance, the expansion slots should be in the main unit, directly connected to the main buses on the motherboard.

The Mac falls short in all four categories. Sure, you can clutter up your desk and spend extra money buying a numeric keypad and a second external disk drive. But you can't have a cursor pad, a color display, or any expansion slots. A mouse is a great editing tool, but it is irritating and difficult to use during keyboard-intensive text entry or when entering numerical data in a spreadsheet. Anyway, with the numeric keypad and second disk drive taking up all your desk space, where are you going to roll the stupid mouse?

As to your problems with the MacTribesmen, you do not have to be converted. The Mac is seriously flawed in both design and execution. Apple had a real chance with the development of the Lisa to set the standard for all future computers. Instead, it assembled a design team of brilliant, but naive, kids and let them develop a nice little toy. Then Apple decided to close the system. On top of that, Apple released a virtually unusable 128K-byte system. Let's hope that all those Mac fans out there get the message and pass it on to Apple. If Apple's arrogance hurts sales enough, maybe Apple and other manufacturers will mend their ways.

David Brandt
Oakdale, NY

Well, you put things a bit more strongly than I would. Stay well.—Jerry ■

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BY BRUCE WEBSTER

Well, I made it. I and my belongings got to Utah relatively intact, and I managed to get everything unpacked and organized a day or two ago, so I'm ready to really start working again. I appreciate your patience over the last few months; these columns have been a little bit sparse, but that should change now.

INDUSTRY UPDATE

It is late September when I write this, and Apple has just announced several new products, including a 20-megabyte hard disk for the Macintosh (reportedly priced at $1495) and a 3½-inch 800K-byte disk drive for the Apple IIe and IIc (at $499). Other products include a new version of the Imagewriter printer and two high-resolution color monitors for the Apple II computers. Not having seen any of them, I can't really comment except to say that it's good to see Apple taking a more aggressive role in the marketplace. I've taken swipes at Apple just about every month, mostly out of frustration at the mixture of brilliance and lack of brilliance coming out of Cupertino. Apple's innovative edge had dulled a little, but common sense seems to be making a strong comeback, and it bodes well for Apple as well as the industry as a whole.

On another front, IBM has been very quiet for the last few months, having said little since announcing that earnings for the rest of 1985 were not going to be very good and that the PC II did not, does not, and will not exist. I am not quite sure what this means, but I see two possibilities: Either the Entry Systems Division is in disarray since the mandated relocation of 200 of its executives from Florida to New Jersey, or IBM is planning to make some stunning announcement and has managed for once to keep it quiet. If it's the latter, the people at IBM will probably have made the announcement by the time you read this—they like the November/December period for such things.

In the Atari 520ST versus Commodore Amiga battle, it appears Atari has won the first skirmish by getting machines out the door, onto dealers' shelves, and into users' homes. Commodore is just this week getting demo units of the Amiga to dealers. I do not yet have either machine. As I type, though, an Atari 520ST is winging its way to me from the BYTE offices in Peterborough. No word yet, though, on when an Amiga might show up. Look for a side-by-side-by-side comparison of the 520ST, Amiga, and Macintosh as systems and development software become available.

Meanwhile, the "Christmas wars" should be over by the time you read this. Going out on a limb, I think that the Atari 520ST will be the big winner, with the Amiga also doing well (but not as well as the Atari). The big loser will be the Apple II, barring a drastic price reduction down to less than $600. Right now, the Apple II falls between the 520ST and the Amiga in price but looks rather pitiful next to either one in performance. The software advantage has carried the Apple II for a long time, but consumers now have some affordable alternatives that make up in sheer power what they may lack in available software. (For more on all this, see the "Predictions for 1986" section later in the column.)

BENCHMARKS AND LANGUAGE SELECTION

Speaking of performance, a discussion of benchmarks has been going on for the last week or two in the Pascal conference on BIX (BYTE Information Exchange). The consensus is that the (in)famous Sieve of Eratosthenes (see listing 1) is not adequate by itself as a benchmark and that you should run several different programs to exercise various aspects of a given compiler or computer. The trick, of course, is coming up with the right set of programs.

What characteristics would the right set of benchmarks have? First, such a set would

(continued)

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need to cover the different aspects of a computer language. The Sieve, at first glance, doesn't do a bad job: It includes integer arithmetic and comparisons, array indexing, loops, and conditional tests. And the Sieve works well for getting "rough order of magnitude" comparisons between languages; for example, the benchmark times shown in my August 1985 column give a pretty good idea of the comparative speeds of, say, MacPascal versus Mac-Modula-2 versus Megamax C. But the Sieve is probably not so reliable by itself for comparing all the C compilers on the Macintosh. Why? The bulk of the time is spent with just a few statements: assigning a constant value to a one-dimensional Boolean (or, for C, integer or short) array, increasing an integer value by another integer value, and testing if one integer value is less than or equal to another. By optimizing those few operations, a compiler/language can look good running the Sieve but might not perform so well with a broader mix of tasks.

Let's say, then, that we're going to design a set (or suite) of benchmark programs for comparing compilers and languages. What aspects should be covered? The list might be as follows:

- Integer arithmetic. Addition and subtraction will be fairly straightforward, since the underlying processor can prob-

(continued)

Listing 1: *The Sieve of Eratosthenes program written in Pascal.*

```
program Prime(Input,Output);
{
  purpose       calculate first 1891 prime numbers 10 times
}
const
  Size                    = 8190;
var
  Flags                   : array[0..Size] of Boolean;
  I,Prime,K,Count,Iter    : Integer;
begin
  Writeln('size of flags:   ',SizeOf(Flags));
  Writeln('10 iterations',Chr(7));
  for Iter := 1 to 10 do begin
    Count := 0;
    for I := 0 to Size do
      Flags[I] := True;
    for I := 0 to Size do
      if Flags[I] then begin
        Prime := I + I + 3;
        K := I + Prime;
        while K <= Size do begin
          Flags[K] := False;
          K := K + Prime
        end;
        Count := Count + 1
      end
end;
  Writeln(Chr(7),Count,' primes')
end. { of program Primes }
```

ably handle them well. Multiplication and division, though, should get special attention, since they're more difficult and time-consuming, making them better targets for compiler or run-time library improvement.

- Real arithmetic. Typically, most compilers call run-time routines to perform real-number math, so speeds will vary widely depending upon how well written those libraries are. My own benchmark experience bears that out, with significant speed variations between different compilers. Also, precision is as important, if not more so, than speed; more on that later.
- Array manipulation. Arrays are the closest thing to a universal data structure, found in just about all programming languages. They should be read from and written to. Multidimensional arrays with multibyte elements provide the best test of performance.
- Character and string manipulation. The perception of computers as number crunchers lives on, but micros probably do more text processing than any other single function. Different types of string manipulations, including assignments and comparisons, are worth timing.
- Manipulation of other data structures, like records or sets. Pascal, C, and FORTH all allow complex data structures; assignment and manipulation of subfields should be timed.
- Control structures. Loops and IF. . .THEN and CASE statements all need to be tested. These are usually straightforward enough, but some care must be taken to provide accurate comparisons. The code within the control structures must have closely matched or well-measured performance between different compilers.
- Subroutine calls. As with control structures, you should be sure you're measuring the call and return performance rather than code within the subroutine or bracketing the call.
- Screen input/output. I/O performance tends to be fuzzy because the operating system often stands in the way. Even so, some compilers handle this better than others. On the other hand, those that perform better often do so at the expense of portability by using machine-specific features.
- Disk I/O. Again, the hardware and the operating system play a big role here, but with those two factors held con-

Table 1: *Times, in seconds, recorded by seven different Pascal implementations running four benchmarks. These programs were all run on the same computer.*

Implementation	Sieve	Matrix	Sort	Reals
1	15.3	4.9	12.3	8.4
2	12.3	9.9	3.1	8.0
3	15.2	12.3	14.6	109.0
4	164.3	13.3	17.2	4.2
5	20.9	4.5	10.7	4.2
6	234.3	27.5	26.9	19.9
7	23.8	12.4	11.5	19.9

stant, language performance can be safely compared.

The second characteristic is that these aspects should be isolated into different programs so that performance in each area can be measured. This isn't always easy: for example, it's hard to test control structures (loops, etc.) without having something in them—but that something might create a speed difference. Likewise, to test, say, integer arithmetic, you may want to set up a loop—but how much effect does the loop have? Still, with work and care you can get a pretty good idea of what aspects of each benchmark program are critical. By separating the benchmarks, you can develop a profile for each compiler or language. This will help you decide which one to use for a particular application.

Third, the issue of true comparison versus optimization must be dealt with. For example, at the start of the Sieve, the array Flags is initialized using a FOR loop. Many compilers and languages support a fast fill routine (such as FillChar in UCSD and Turbo Pascal or the FILL word found in many FORTH implementations); using such implementation- or language-specific features can speed execution, while strict adherence to an independent form provides a more "accurate" (though possibly less relevant) comparison. So the question is this: Should the benchmark programs be adjusted for each compiler/language to take advantage of special features, or should they remain as identical to other versions as possible? This is another argument for a set of benchmark programs; with multiple programs, you reduce the possibility of a specific feature or extension resulting in deceptively good performance for a single program.

Finally, be aware of compiler options that can affect speed. Turbo Pascal, for example, has a number of options (range checking, user interrupts, etc.) that are turned off by default, resulting in very fast execution. If you turn just one of them—$U+, for user interrupts—back on, your benchmark programs will slow down by a factor of 10 or so. In contrast, IBM Pascal (version 1.0) has a number of similar options (covered by the metacommand $DEBUG) turned on by default, resulting in slower execution. When you run benchmarks, make sure that the compiler options are identically set, preferably with as many options turned off as possible.

INTERPRETING BENCHMARKS

Once you've run those benchmarks through a number of compilers or languages, you may find that the results are not as clear-cut as you would like. A particular implementation may do well with a few of the benchmarks, so-so with some others, and poorly with one or two. For example, table 1 shows the results of running four benchmarks—the Sieve, an integer matrix multiplication, a string sort, and a real-number arithmetic exercise—through seven different versions of a particular language on the same computer. Note the dramatic differences. For example, imple-

(continued)

mentation #3 looks pretty good with most of the benchmarks but does horribly with the real numbers. Likewise, implementation #4 beats all the others with the real numbers (except for #5, which it ties) but is terribly slow on the Sieve and less than exciting on the other two. Implementation #5 seems to be the closest to an all-around winner; it comes in first on the second and fourth benchmarks and does acceptably well on the first and third. (For those of you dying of curiosity, the different implementations are unmasked at the end of the column.)

So the question is this: Which one do you go with? Well, as with just about any decision involving micros, "That depends." Upon what? Upon what you want to do with it. If you're going to be doing a lot of real-number calculation, you probably won't choose implementation #3. Likewise, for functions similar to the Sieve, you don't want #4 or #6. But performance alone may not give you sufficient information to select one compiler or language over another. For example, the benchmarks for implementations #1, #2, and #5 are close enough that, for a general mix of functions, performance is going to be pretty much equal. So how do you choose?

MORE THAN SPEED

Once you have eliminated performance as a criterion for selecting a compiler or language, you should consider other factors. Some of these are

- Precision of real numbers (mentioned above). There are many pitfalls in doing real arithmetic, like cumulative round-off errors, subtraction of nearly identical values, and so on. Compilers typically have a set of library routines for doing real arithmetic; the quality of these routines can dramatically impact the quality of your results beyond the simple issue of how many significant digits the compiler supports.
- Memory models. Most compilers perform well for small programs; what happens when you want to write a large one? How large a program can you have? How much memory can you actually use, and what can you use it for? What mechanisms exist for getting around those limits?
- Compiler size and speed. This wasn't considered an issue until Borland International released Turbo Pascal, which was an order of magnitude smaller and one or two orders faster than anything else out at the time. I, for one, wonder now why many other compilers are so big and so slow.
- Adherence to standards. This can be for the language itself or for the libraries supplied. Again, Turbo Pascal has been controversial in this respect; critics have pointed out the ways in which Borland ignored the ISO (International Standards Organization) and Wirth definitions and the problems caused thereby, while apologists have countered by claiming Turbo itself is a de facto standard because more copies of Turbo are in existence and use than any other Pascal implementation (and, probably, more than all other implementations combined).

- Access to hardware/ROM (read-only memory)/operating system. How well does the compiler let you use the computer you're running on? This can include graphics, I/O ports, mass-storage devices, math coprocessors, and calls to ROM or operating-system routines.
- Utilities. Does the language have support programs, like editors, debuggers, linkers, and libraries? How many are included in your package, how much do the rest cost, and how well do they work?
- Cost, licensing, technical support, and upgrades. If you're planning to do a lot of work in a given language, cost is not that big an issue (unless, of course, you don't have the money). If you're planning to do commercial work, licensing is a big issue, although more and more firms are dropping licensing fees (inspired, perhaps, by the death of SofTech Microsystems, which used to ask incredible fees). Likewise, good technical-support and upgrade policies are important for serious development, since most compilers are undergoing constant improvement.
- Your environment. If all your coworkers are using C, it may not be a good idea to select Pascal, and vice versa. This is especially true if someone else is going to maintain your program (fix bugs, add features, etc.) after you've written it.
- Aesthetics and philosophy. Some people really like C; others swear by Pascal; yet others prefer FORTH, or LISP, or assembly language, or even (gasp!) BASIC. The reasons are many, complex, and often inalterable; in this respect, a person's language preference becomes as firm as religion or politics. What's really ironic is that, given all the benchmarks and other valid issues, this last point is often the deciding one, and the others are shamelessly manipulated to support the predetermined decision.

As you can see, there is much, much more to consider in selecting a given language or compiler than how fast it runs the Sieve program. Of course, this is all assuming that you're running on one given computer. If we start talking about different configurations (memory, disks, etc.), not to mention entirely different computers, the issues become even more complex.

PREDICTIONS FOR 1986

I'm not sure what it is that makes us get such a kick out of trying to predict the future, but it is fun. I am, perhaps, a bit unwise to try it myself; not only am I writing this before 1986 even starts (late September, to be exact), but I don't have much in the way of inside information, especially living up here in the Rockies. But, as the song says, I've been a fool for lesser things, so here goes.

- There will be a big upswing in the "mythical" home computer market. This will start toward the end of 1985 and will continue strong through most of 1986. What's more, the public—having learned their lesson from the millions

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of C-64s, TI-99/4As, and VIC-20s gathering dust on bookshelves—will be willing to put out the bucks to buy powerful, expandable computers. The result is that...

• Commodore and Atari will both do well, much to everyone's surprise. People will buy the 520ST and the Amiga, looking for a system that can do serious work and yet run nifty games. The Apple II has been the only computer on the market for years that has really filled that bill, and its aging technology has caught up with it. This means that...

• Sales of the Apple II will plummet, only to be spurred again by dramatically reduced prices. This, of course, will hurt Apple, since the IIe/IIc models have been the real cash cows, helping to subsidize the Lisa and the Macintosh. As a result...

• Apple will be scrambling, trying to rectify its mistakes of the last two years. The computer-as-toaster concept of the Macintosh has failed. It remains the easiest computer around to use, but the crippling hardware limitations have held it back. A Mac-like machine with slots, a fan, a faster processor and disk drives, more memory and mass storage, a larger display, and possibly even color will be released. With these changes...

• An MS-DOS card for the new Macintosh will be released. Probably not from Apple, it will most likely come from either Dayna Communications (the MacCharlie people) or AST Research. The card will have cables leading to a pair of 5¼-inch disk drives, and the whole system will let the new Mac look like an IBM PC. Once this happens...

• The Macintosh will finally start to penetrate the corporate business market—two years late, and in nowhere near the numbers that Apple had hoped. Nevertheless, it will generate some cash and (more important) confidence from Wall Street, sending Apple stock up from its long-term slump. However, in the meantime...

• An MS-DOS box—with 8088 processor and a BIOS (basic input/output system) from the folks at Phoenix—will be released for the Amiga. It will plug into the Amiga's expansion bus and take over the machine, using the 68000 as an auxiliary I/O processor. It may have its own 5¼-inch drives, or it may use the optional 5¼-inch Amiga drives. At the same time...

• UNIX, despite its many serious flaws, will also do well, much to everyone's surprise (except all those UNIX hackers who have sworn by it all along). Versions of UNIX will appear almost simultaneously for the new Macintosh, the Amiga, and the upgraded (1-megabyte) 520ST. All three machines will become popular in university and engineering environments, as those same UNIX hackers discover the delight of having a computer all to yourself. The upshot of all this is that...

• The 68000 will have a good year, not only because of the successes of the new Mac, the Amiga, and the 520ST, but because of other 68000-based systems aimed at home, educational, and scientific markets. Indeed, the 80x86 versus 680x0 dichotomy will cause déjà vu in those who have seen the IBM versus DEC mainframe and mini-

ACCORDING TO WEBSTER

computer market divisions over the years. Speaking of whom . . .

- IBM will mostly sit on its lead (and its hands), content to rely on momentum and its name to sell products. The only new product to see the light of day will be its laptop portable, which will be decently designed but poorly marketed and received. Instead, this market will be snatched up by the clone-makers, much as the desktop portable market was, and possibly by the same firm: Compaq. And speaking of the clone-makers . . .
- IBM-compatible computers will continue to grab a larger share of the business market, eating into IBM's sales. Should IBM be so foolish as to introduce a proprietary operating system, that share will actually Increase, as both software developers and consumers shy away from locking themselves into IBM-only software and hardware.

Well, that's that. Those are my predictions for 1986. A year from now, I'll review them and see how I did. None are terribly dramatic, and there will undoubtedly be major developments that are unanticipated here.

IN THE QUEUE

Well, the Atari 520ST arrived safe and sound and is now set up and running. Next month's column will be devoted to first impressions of the machine, which I think will sell very well. I'll also look at a significant piece of development software for the 520ST: a native-code Modula-2 compiler from TDI Software Ltd. Other programming tools will be covered, too, including two new native-code Pascal compilers for the Macintosh and a useful set of diagnostic tools for Turbo Pascal development under MS-DOS. An Amiga computer is now on its way, so the following month (March) will have benchmarks and other comparisons between the Mac, the 520ST, and the Amiga.

AND THE ANSWER IS . . .

For those of you who are curious as to the identities of the language implementations in table 1, here's the story. All of these are Pascal implementations running on a Compaq portable under MS-DOS 1.1. Since all were done in the spring of 1984, they are out of date; new versions of most (if not all) of the implementations have since been released. If I had had the latest versions of all the Pascals, I would have rerun the benchmarks, but I didn't. As such, these should *not* be considered accurate or current. The envelope, please:

#1: Turbo Pascal, version 2.0, Borland International
#2: IBM Pascal, version 1.0, IBM (Microsoft)
#3: Pascal/MT+, version 3.1, Digital Research Inc.
#4: UCSD Pascal, version IV.1, Network Consulting Inc.
#5: Same as #4, but run through the native-code generator
#6: UCSD Pascal, version IV.1, SofTech Microsystems
#7: Same as #6, but run through the native-code generator

Incidentally, these were all run with as many compiler options turned off as possible. ■

Technical Bulletin
No. 2 in a series.

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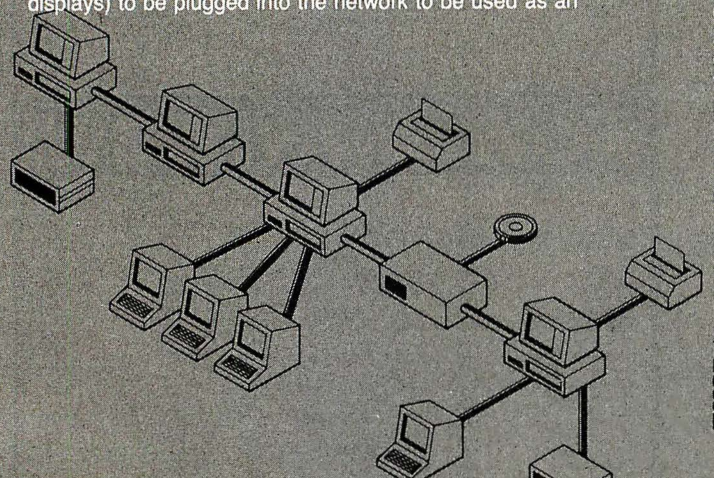
O/S	Computer	Processor	Measured time
QNX ™	IBM-PC AT	80286	480 usec
XENIX ™	Intel-286	80286	4,930 usec

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Designed with extensive file security features, QNX 2.0 provides login protection with network wide file permission checking based on 255 groups of 255 users. In addition, each PC user may control network access to devices attached locally to their machine.

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Basic Compiler	Isam File Utility
Qbol (dibol) Compiler	Networking Board
Text Processor	OEM Customization Kit (to port QNX)
Real Time Spelling Checker	

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バイト

Favoring Kanji

NEC's PC-98XA, PC-9801VF2, PC-9801VM2, PC-9801VM0, PC-9801U2, and V30, DynaMac, EgWord, EgBridge, and FM-16π

BY WILLIAM M. RAIKE

As this is being written, the autumn *O-bon* holidays are behind us, along with the last of the muggy weather. It looks as if I may finally catch up with some postponed chores, like having the straw covers of my *tatami* mats turned over, mending the paper *shoji* screens on my sliding doors, buying new *futons* (sleeping mats), and checking the disk drives for mildew.

NEC Upgrades the PC-9801

Recently, NEC has introduced so many new models in its PC-9801 series that I wonder if it's been taking its cues from automobile manufacturers. The most popular personal and office computers in Japan, the PC-9801 series is the domestic version of the APC III that NEC sells in the U.S. I first mentioned the PC-98XA in BYTE Japan last October (page 381); it's the top-of-the-line model, based on the 80286 microprocessor (the same one IBM uses in its PC AT). In the same column, I mentioned the oddly timed introduction of the PC-9801U2, a version that uses 3½-inch microfloppy-disk drives and has less main RAM (random-access read/write memory) and graphics video RAM than the mainstays of the product line, the F2 and M2 models. All the previous PC-9801 models had been based on the 8086-2 microprocessor, and they differed primarily in the capacities of their built-in 5-inch floppy-disk drives. NEC uses the suffixes U2, F2, M2, M3, etc., to distinguish among PC-9801 models with different disk-drive configurations, memory capacities, etc., but they are all just variations of the basic PC-9801.

Besides the PC-98XA, the new-model line-up includes the PC-9801VF2, VM2, and VM0, in addition to the PC-9801U2. NEC has switched over to a microprocessor it developed itself, the V30, instead of using the 8086 originally developed by Intel Corporation in the U.S. The V30 microprocessor (its actual designation is the μPD-70116) is completely software-compatible with the 8086, meaning that it can run all programs that run on the 8086 or 8088 microprocessors used in most current 16-bit computers. The only difference is that it executes them quite a bit faster—typically 30 to 50 percent—even when running at the same clock speed. In the VM0 and VM2 models, a slightly faster version of the V30 is used, and there's a switch so that you can select either of two clock speeds. The 8-MHz rate is compatible with older versions of the PC-9801 line, for programs that involve critical timing loops and the like, while the 10-MHz rate gives a 25 percent speed boost. Unfortunately, the 10-MHz rate is too fast for the old-type expansion RAM boards, so people upgrading from the older PC-9801 models will either have to use the slower 8-MHz clock rate or buy the new high-speed expansion boards NEC sells along with the new machines.

The F in the VF2 suffix refers to the 640K-byte floppy-disk format; the 2 means there are two built-in 5¼-inch floppy-disk drives. The VM0 model has no built-in floppy-disk drives, although it does house both 5¼- and 8-inch interfaces because it's designed for users who intend to use external disk drives or for factory-automation applications. The VM2 has two built-in 1-megabyte floppy-disk drives, although in this model they are also supposed to be able to read disks recorded on earlier NEC machines in either 640K-byte or 320K-byte formats. Based on the experiences of people I know with earlier models of the PC-9801, I suspect that the ability to read disks recorded in different formats depends on which operating system you use.

The NEC machines can run Japanese-language versions of either CP/M-86 or MS-DOS. NEC spokespersons say the company plans to make CCP/M, Microsoft Windows, and MS-DOS 3.1 available here in the near future. In the past, the PC-9801's ability to read various disk formats hasn't worked for people running under CP/M-86.

(continued)

William M. Raike, who has a Ph.D. in applied mathematics from Northwestern University, has taught operations research and computer science in Austin, Texas, and Monterey, California. He holds a patent on a voice scrambler and was formerly an officer of Cryptext Corporation in the United States. In 1980, he went to Japan looking for 64K-bit RAMs. He has been there ever since as a technical translator and a software developer. He can be contacted c/o BYTE, POB 372, Hancock, NH 03449.

The long-awaited Japanese-language version of the Macintosh is finally in the showrooms here.

Other improvements that are now standard were extra-cost options on earlier models. For instance, all models now include a full 6000-plus kanji-character ROM (read-only memory), and the VM2 and VM0 models now have 384K bytes of RAM, while the VF2 has 256K bytes. A mouse interface is now standard on all models, too, as are 192K bytes of graphics video RAM (except on the U2 model, which has only 96K bytes of graphics video RAM and 128K of main RAM).

Although discounts of 20 or even 25 percent are common, the list prices of these computers are not too high considering the technology they represent. The PC-9801VF2 costs about $1480, while the PC-9801VM2 costs about $1765. The VM0 model costs only about $1255. If these prices sound a little higher than those I've mentioned recently in this column, it's because they reflect the recent drop in the value of the dollar against the yen.

DYNAMAC

When I reported on last year's springtime computer shows, I had very little good to say about Apple's attempts to introduce the Macintosh to the Japanese market. You can now find features like mice and windows as low-cost options on Japanese-made computers (along with plenty of software). The biggest drawback of the Mac at that time was that it couldn't speak Japanese (except for some strange katakana displays kludged up using graphics).

But Apple's reshuffling of its Japanese distribution setup and its linkup with Canon seem to have made a difference. The long-awaited Japanese-language version of the Macintosh is finally in the showrooms, and it looks as if it's been done properly and professionally. They've piggybacked a small kanji-character ROM board onto the main board of a 512K-byte Macintosh and written some software to take advantage of it. The result is the DynaMac. It's a package consisting of a 512K-byte Macintosh with the kanji ROM installed (no, it's not available in the U.S.), an external disk drive, and a printer. (The printer is the Seikosha SP 1000 AP, which offers a very readable kanji font, but you can order the standard Apple Imagewriter instead.) The kanji ROM incorporates only the JIS (Japan Industrial Standard) No. 1 set of 3400 or so characters, which is enough for lots of applications, although all the top-ranking Japanese personal computers also include the additional 3000 or so characters in the JIS No. 2 character set. The limitation is unlikely to be serious because, like other Japanese machines, the system includes the ability to incorporate additional user-defined kanji in the phrase dictionary stored on a floppy disk.

I visited the exhibition where the DynaMac made its debut, courtesy of HI-TECS Company Ltd. in Tokyo, a local Apple distributor. In contrast to similar earlier affairs staged by other companies, the demonstrations were professionally organized. There were plenty of machines available, and there was enough well-informed staff on hand that no visitors ended up wandering around looking lost. I asked to see a demonstration of the Japanese-language word-processing program first. It makes effective use of the mouse and pull-down windows, and it seemed at least as usable and powerful as some other popular programs, including the JWORD package that came with my previous Fujitsu computer.

THE CONVERSION PROCESS

The real key to evaluating a Japanese word-processing program is how well

it performs kanji conversion. A kana shift, available on all Japanese personal computers, lets you use each key to input one or two katakana (or hiragana, depending on the manufacturer) phonetic characters. But most people are unfamiliar with the layout, and typists generally prefer to enter Japanese text phonetically using the Roman alphabet rather than the kana alphabet. The conversion routine then looks up the appropriate kanji characters in a stored dictionary. Sophisticated programs accept entire phrases, rather than individual words or even individual syllables. The EgWord program that comes from HITECS with the DynaMac does that. (EgWord is not pronounced the way you might think. Because Japanese are taught to mispronounce the word "easy" as "eejee," the spelling of EgWord is an attempt to systematize a mispronunciation of "easy word.") As you type with EgWord, the phonetic katakana characters corresponding to the Roman letters typed on the keyboard are displayed in a screen window. When you reach the end of a phrase or sentence, pressing one of the mouse buttons causes the machine to look through its phrase dictionary, which is partly in memory and partly on a floppy disk. It then converts the phonetic text to ordinary Japanese, which is a mixture of kanji characters and phonetic hiragana characters used primarily for inflected word endings (e.g., verb tenses).

The conversion is a fairly sophisticated task because there are many kanji characters that are pronounced the same but have completely different meanings. A good conversion routine has to guess the right kanji correctly from context a high proportion of the time. Of course, if the computer's first guess is not the characters you really wanted, you can back up and examine alternative character combinations one by one, using the mouse for selection. Lots of good Japanese word-processing programs do this; this one does it as well as most.

EgWord does have some shortcomings, however: It doesn't handle English-language text input very well (it doesn't have word-wrap, for example, because it's unnecessary in Japanese), and the distinction between standard-width and double-width Roman letters, important for professional-looking Japanese text, is handled clumsily.

Bridging the Gap

In addition to EgWord, a program called EgBridge (similar pronunciation reasoning as in EgWord) is supplied with the DynaMac. EgBridge is a pro-

(continued)

Whether the Mac will be able to compete against sophisticated Japanese hardware and increasingly versatile Japanese software will probably be decided by prices.

gram that lets you enter Japanese characters as well as conventional alphanumeric characters into standard Mac software like Multiplan, MacPaint, MacProject, Microsoft Chart, and Microsoft File. It doesn't convert the English-language messages built into the original program, but it does allow you to enter Japanese text. Even though the resulting screen displays are a hodgepodge of English and Japanese, EgBridge is an attempt to bridge the gap between the worlds of western software and the Japanese language.

EgBridge is much more limited than EgWord; it does kanji conversion on a syllable-by-syllable basis, and it requires a user-supplied kanji dictionary (up to 3000 characters). Nevertheless, companies like HI-TECS are offering customized versions of standard software packages for purposes such as inventory management, building design, scheduling, sales management, etc., at prices ranging from about $550 to $800. The president of HI-TECS, Mr. Haneda, says they'll put together any kanji dictionary the customer wants at no extra charge.

All in all, this is the first time that the Mac has had a chance to succeed in Japan. Whether it will be able to compete against sophisticated Japanese hardware and increasingly versatile Japanese software is another story—one that probably will be decided by prices. HI-TECS is offering the DynaMac, including the kanji ROM, printer, and external floppy-disk drive, for the equivalent of about $4575 and will throw in EgWord, which normally sells for about $240, for early customers. Since that's nearly double the price of systems like the new NEC PC-9801VM2 or the dual-floppy-disk version of the Fujitsu FM-16β with a good kanji printer, people are really going to have to be impressed with the DynaMac for it to be a commercial success. Mac enthusiasts who want more information on this machine can contact HI-TECS Company Ltd., 4-1 Kodemmacho, Nihonbashi, Chuo-ku, Tokyo 103, Japan.

More on Fujitsu's FM-16π

In last August's BYTE Japan (page 331) I reported on the debut of the then-anonymous lap-size portable computer from Fujitsu. The machine is now called the FM-16π. It's been on dealer's shelves for some weeks, and even though it's not a technological wonder, I think it's a tremendous value. If I needed a lap-size computer (it's about two inches thick and the size of a sheet of stationery), I'd think seriously about buying this one.

The main processor is an MBL8086L, a CMOS (complementary metal-oxide semiconductor) version of the 8086 microprocessor, running at a clock speed of 5 MHz. The machine comes in three versions, with a main RAM of either 128K, 288K, or 488K bytes. It is available with either the standard JIS (alphanumeric and katakana) keyboard or a phonetically arranged "goju-on" keyboard layout. A kanji ROM containing the 3400-odd JIS No. 1 set of characters is standard, and the ROM also includes a 19,000-word kanji dictionary for Japanese word-processing purposes. The liquid-crystal display is one of the best I've seen; it's far easier to read, for example, than that of the Data General/One. It can display 25 lines of 80 alphanumeric (or kana) characters, or 11 lines of 40 kanji characters in a legible 16- by 16-dot font. You get a built-in floppy-disk interface and bar-code-

reader interface as standard, in addition to a parallel printer interface and an RS-232C serial interface. There's no built-in modem, because by the time you read this, it will only just have become legal to hook up a direct-connect modem to the Japanese phone system; however, you can buy a separate acoustic coupler.

Unfortunately, the FM-16π doesn't have a built-in microfloppy-disk drive; instead, like the Epson laptop machines, the machine has a microcassette drive built in. Supposedly, you can write over 200 characters per second to the tape; that comes to about a minute for a 10-page document, which is too long if you plan to save your word-processing results frequently. Nonetheless, I think I could live without a built-in floppy-disk drive. The machine runs under the CP/M-86 operating system, and you can configure part of the main RAM as a RAM disk, which ought to be acceptable for medium-term storage, since a backup battery makes the CMOS RAM relatively nonvolatile.

You can buy software in the form of optional ROM cartridges that sell for a little more than $200 each. Right now you can choose from two cartridges: one includes Fujitsu's version of BASIC plus a communications program and the JWORD Japanese word-processing program, while the other contains the kanji COBOL Level II run-time system and a communications program.

I have only one reservation about the FM-16π. The keyboard feel and layout are both good, with one glaring exception: The space bar is actually three short bars, and only the middle part (extending from just under the middle of the V key to just under the middle of the N key) works as a space bar. The outer parts are intended to control kanji conversion when you use a Japanese word-processing program. They are labeled (in Japanese) "Convert" and "No conversion"; they have no effect in the alphanumeric mode. For me, it made ordinary typing very inconvenient and almost intolerable. I suppose you could get used to it, but I'd be tempted either to "hot-wire" (cut and jumper) the keyboard (and I don't know if that's feasible) or to glue a steel bar over all three segments!

The FM-16π is reasonably priced. You can buy the 128K-byte version for only about $810, while the prices of the 288K-byte and 488K-byte versions are only about $1020 and $1225, respectively. You'll have to buy one in Japan, though; they're not exported.

Coming Up

In the February issue, I'll focus on two shows I attended here in Japan in October—one on software and the other on data. I'll also discuss highlights of several new printers. ■

The Acorn RISC Machine

A commercial RISC processor

BY DICK POUNTAIN

Acorn Computers Ltd. is one of the U.K.'s most successful computer companies, but like many others, it had its share of financial problems during the depressed year of 1985. Set up in 1979 by two Sinclair alumni, Chris Curry and Hermann Hauser, the Cambridge-based firm (4a Market Hill, Cambridge CB2 3NJ, England) started out manufacturing a set of modular single-board controllers based on the MOS Technology 6502 processor. These small boards stacked together to make up complete industrial-control systems. The following year the Acorn people launched the Atom personal computer, a packaged but expandable machine that arose out of their experience with 6502 systems. For a while, at around £200, the Atom was the cheapest hobby computer available here, and it attracted a strong following, particularly among those who are as handy with the soldering iron as with the assembler. Hopped-up Atoms can still be found to this day.

Acorn's next product, initially called the Proton, was designed to meet a very advanced—for the time—specification published by the BBC (British Broadcasting Company), which was requesting bids to supply a personal computer around which an educational television series would be produced. Acorn won the contract, after a strong and often acrimonious contest in which Sinclair Research, whose 48K-byte color Spectrum was already on the market, lost out.

After a frustratingly long delay due to quality-control problems with the ULAs (uncommitted logic arrays), the BBC computer was launched and proceeded to corner the market in schools and universities. Acorn became a very wealthy company, with a turnover reputed to be £100,000,000 per annum at its high point.

The BBC Micro (alias the Beeb) is still quite a deluxe machine, with better high-resolution color graphics than any of its competitors, and quite a bit faster, thanks to its 2-megahertz 6502. Another plus is the provision of a 10-MHz bus, called the Tube, to which second processors can be attached. Acorn charges a lot of money for this sophistication though, and the Beeb has kept its £400 price long after competitors have slashed theirs to below the £200 mark.

Acorn had from the start paid more attention to software than most manufacturers, recruiting the brightest Cambridge University computer science graduates for its software division. As a result, the Beeb acquired a range of languages unrivaled by any machine but the Apple II, including an advanced structured BASIC, LISP, Logo, FORTH, Pascal, BCPL (Basic Combined Programming Language), and more. But despite all these positive points, the Beeb has a major drawback, a shortage of memory. The ambitious specification, combined with the limited addressing capabilities of the 6502, left it with a maximum of 32K bytes of workspace (only this year upgraded to 64K bytes), and in the higher-resolution graphics modes this can be reduced to a mere 8K bytes. That doesn't get you very far in LISP or Logo.

So at the height of its prosperity, Acorn set a team to design, in secret, its own processor to replace the 6502. This may seem like an ambitious, even rash, undertaking, but the people on the Acorn team were so wedded to the simplicity and speed of the 6502 architecture that they found it hard to countenance any of the commercially available 16-bit replacements. The BBC operating system is heavily interrupt-driven, and the sluggish interrupt latency of 16-bit chips, such as the Intel 8086 and Motorola 68000, would have meant introducing DMA (direct memory access) hardware and all sorts of other undesirable complications. Acorn did, in fact, adopt the National Semiconductor 32016 as a second processor for the Beeb, but only after first offering a 3-MHz 6502. And so they conceived the idea for the

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THE ARM

The ARM was a very well-kept secret indeed. Until its announcement in August 1985, when it had already been created and was available in sample quantities, no word of its existence appeared in the computer press.

Acorn's designers worked in collaboration with the U.S. firm VLSI Technology Inc. (San Jose, CA) who supplied them with CAD (computer-aided design) workstations and design software and made the chips. The Acorn team already had some experience in VLSI (very-large-scale integration) design from working on the ULAs for the BBC microcomputer, but none in processor design. At the time these were some of the most complex ULAs ever made. In a mere 18 months the Acorn team designed ARM from scratch, and it worked as specified from the first silicon. This is not only a great testament to Acorn's design skills, but also a remarkable vindication of the RISC design philosophy. (See "RISC Chips" by John Markoff, November 1984 BYTE, page 191.) It's highly unlikely that such a feat could have been achieved using any of the colossal architectures currently in fashion, like the 68020.

The Acorn people on the design team were inspired by the virtues of the venerable 6502 and by other RISC researchers, such as those on the Stanford and Berkeley teams. However, they departed in several ways from previously used techniques. The design goals they set were high execution speed, a small and regular instruction set, and a very short response time to interrupts (in particular, one much better than that of present 16-bit chips). In addition, the Acorn people required that the chip be capable of supporting virtual-memory operation. Since they started in 1984, it made sense to go straight to a 32-bit processor, as the 16-bit era was already drawing to a close.

The ARM design started, quite properly, with the instruction set rather than the hardware. In fact, the whole design, debugging, and proving of the chip were performed by software simulations—some running on BBC microcomputers with the 3-MHz 6502 second processor—with no hardware prototype at all. The first fabricated chips were also the first hardware realization of the project.

ARM uses a heavily pipelined architecture to achieve a performance of 3 MIPS (million instructions per second) from a small (7 millimeters square) chip containing 25,000 transistors. For comparison, the 68020 is around 9 mm square, contains 192,000 transistors, and achieves about 2.5 MIPS. Clocked at the equivalent of 5 MHz, ARM runs BASIC benchmarks almost exactly 10 times faster than the IBM PC AT and comfortably faster than the TDI Pinnacle with its 12-MHz 68000. The first version of ARM uses fairly conservative 3-micron CMOS (complementary metal-oxide semiconductor) design rules with double metal level and uses so little power that it doesn't become even detectably warm in use. The device is packaged on a square 84-pin Jedec chip carrier.

Later versions will go to 2.4-micron design rules, resulting in an even smaller chip. A smaller chip means a higher yield, and Acorn estimates that it will be more than four times cheaper to manufacture than current megachips such as the 80x86 and 680x0 series. Acorn hopes to sell it to manufacturers of low-cost personal computers, as well as to the artificial intelligence workstation sector.

ARM has 25 full 32-bit registers, a 32-bit data bus, and a 26-bit address bus that enables it to address 64 megabytes of memory to byte boundaries. Only 16 registers are normally available to the programmer. During interrupts the extra registers become available to the processor to simulate a DMA channel without needing to save any of the user's registers. Register 15 contains the program counter; it also holds the status flags in its first 6 bits, there being no separate flags register.

All instructions are 32-bit words

(continued)

(aligned on word boundaries), divided into several fields, and fetchable in one clock cycle. All operations are performed on 32-bit quantities. If you wish to fetch bytes, certain of the load-and-store instructions will extract them and zero-extend them to 32-bits, making use of the on-chip barrel shifter. The advantage of this scheme is that having everything the same length simplifies instruction fetch and sequencing. A potential disadvantage, shared by many RISC designs, is that a minimum 4-byte instruction generates a lot of code compared to older machine designs. With today's memory prices, however, that is not too great a concern.

There are 44 basic instruction codes that can be divided into five categories: load-and-store single-register, load-and-store multiple-register, arithmetic and logical, branch, and software-interrupt instructions. ARM supports no multiply or divide instructions. Each instruction type has several fields, and by setting appropriate option bits you can synthesize a large number of different instructions from the basic set.

Following the Berkeley and Stanford models, ARM has a load-and-store architecture. Only the load-and-store instructions can access memory, and all operations on data are register-to-register.

All the instructions are conditional; that is, they include a test that must be true before they will execute. The first 4 bits of each op code are used to select one of 16 possible conditions. This reduces the number of branches required in a program because branches reduce the efficiency of pipelining. When a program takes a branch, it has to throw away the next (already fetched and decoded) instructions; this causes a time-consuming break or "bubble" in the pipeline. You can write many programs without branches using this "skip-on-test" feature, which is available in every instruction.

The ARM has only two addressing modes: base-relative and program-relative. However, you can easily synthesize other modes from these. Base-relative mode permits either a 12-bit immediate value or a second register—in each case shifted if necessary by the barrel shifter—to be used as the offset. The result of this offset operation may be optionally rewritten to the base register—signaled by turning on a "rewrite" bit in the instruction. Since offsets may be positive or negative, it's easy to get the same effect as the 68000's pre- and post-automatic decrement and increment modes.

The ARM's barrel shifter is also used for arithmetic and logical shifts and (without programmer involvement) to align data words and to extract fields from instructions. As an example, to multiply a number in a register by 17, ARM could add the number to itself shifted left four times and could do it in a single clock tick.

Branches use a 24-bit offset that allows branching to anywhere in memory. There are no separate long and short jumping instructions and no reason to want them, as they would save neither space nor time. If you set the optional "link" bit in the branch instructions, register 15 (the program counter) is copied into register 14 as a return address so that jumps and subroutine calls and returns are accomplished by the same instruction.

All ARM instructions can be executed in one clock tick, except for the load-and-store multiple-register instructions, which require one tick per register. These load-and-store multiple-register instructions provide a fast way of saving the processor state and, therefore, very efficient context switching for procedure calls in high-level languages.

Figure 1 is a block diagram that

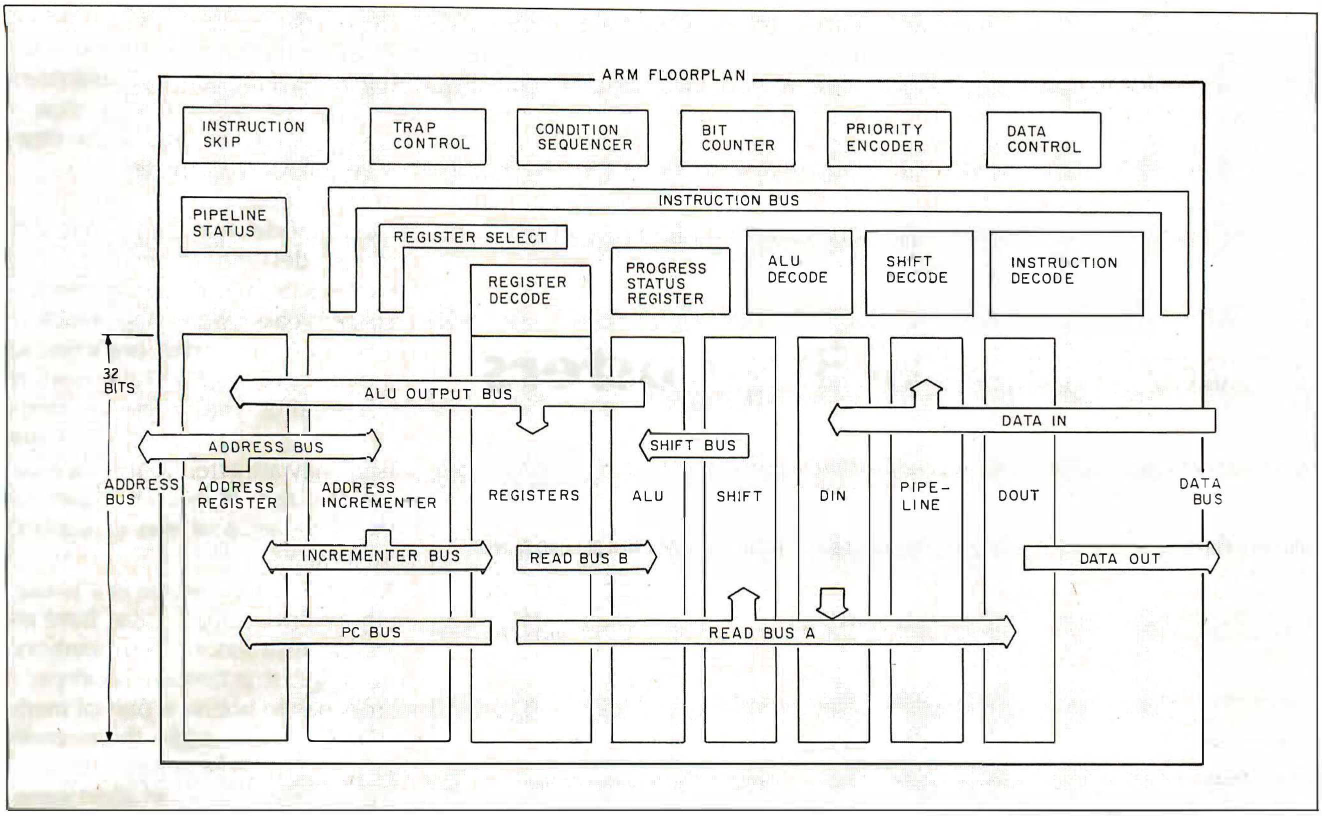


Figure 1: *Block diagram of the 32-bit data path through the ARM chip and some of ARM's main functional units.*

shows the 32-bit data path through the ARM chip and some of ARM's main functional units. The flow of data through this pathway is not controlled by a single control unit, as in conventional processors, but by a number of separate functional units. The instruction decoder is a programmable logic array in which the instructions are hard-wired. There is no microcode ROM (read-only memory); indeed

(continued)

there is no microcode. Bits in the actual instruction word provide most of the control information.

ARM may fetch an instruction from memory while the previous instruction is being decoded and that instruction's predecessor is finishing execution in the ALU (arithmetic logic unit). This state of affairs, which maximizes processor throughput, persists as long as ARM is performing register-to-register operations consecutively without branching. The load-and-store architecture pays dividends in pipeline efficiency. Acorn has measured ARM's maximum processor-to-memory bandwidth (the rate at which it can transfer data) at 18 MHz.

The condition-sequencer and instruction-skip units implement the skip-on-test feature. If the current instruction's condition test fails, the instruction is discarded without breaking the pipeline of following instructions.

Acorn departs firmly from the Berkeley model, however, on the subject of delayed branching. The Berkeley RISC avoids the problem of pipeline breaks by delaying branch instructions; it redefines branches so that they take place *after* the next instruction; thus, you can always safely prefetch the next instruction. Acorn was initially attracted to this idea but later rejected it because part of Acorn's design goal was to support virtual memory.

A processor that works in a virtual-memory environment must have restartable instructions; if a memory-accessing instruction—for example, a store—tries to access a part of memory that is not available, the memory manager will order an abort. When the processor receives an abort signal, it must restart the offending instruction, having restored the processor state and taken some appropriate remedial action. With a delayed branching scheme, this is difficult to do if an abort occurs while prefetching the instruction following a branch.

Acorn's team instead chose the skip-on-test route and thus has made all the ARM instructions restartable. However, the hardware itself won't do all the repair work; it only preserves the information necessary so that user-supplied software routines can restore the processor state.

ARM has achieved the desired short interrupt latency, partly thanks to the virtual absence of uninterruptible multicycle instructions and partly due to the presence of dedicated system registers that avoid the need to save user registers.

ARM's extremely high processor-to-memory bandwidth is achieved by the wide nonmultiplexed data and address buses and the quite modest cycle time (150 nanoseconds) and therefore does not need to employ expensive static-memory parts. The chip has control signals that can extract 30 per-

cent extra performance from cheap 4-MHz dynamic RAMs (random-access read/write memories) by exploiting page-mode cycles.

SOFTWARE

Unlike most new chips, ARM is already quite well supplied with software. Acorn has a small concurrent operating system running on the chip, derived from that on the BBC computer. Acorn showed me a BBC BASIC interpreter and a LISP compiler working with a windowing full-screen editor. Compilers for BCPL and Modula-2 are also available, while C, Pascal, FORTRAN, and Prolog are all in the works to cater to the scientific and artificial intelligence communities.

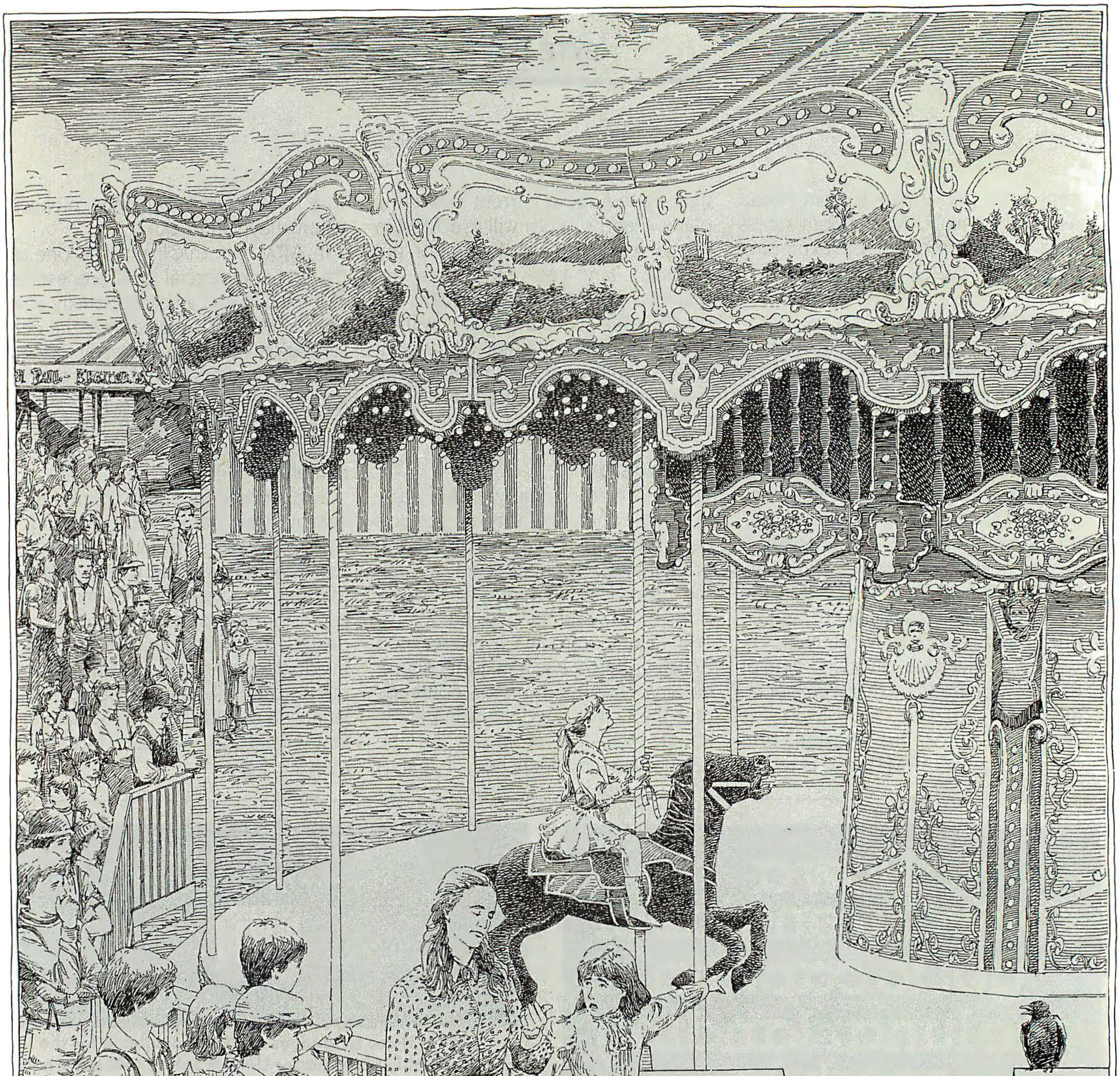
Acorn's business division, one of the new departments that were set up after the takeover by Olivetti, is responsible for the design and manufacture of ARM, but it is rather tight-lipped about current marketing plans. Clearly, Acorn will use ARM in future products, but it has not announced any yet. Acorn has announced that an evaluation board will be available soon and that it will be selling the chip to other OEMs (original equipment manufacturers), several of whom have had evaluation units for some time.

CONCLUSION

The Acorn story nearly ended early in 1985, when the City of London panicked and drove Acorn's shareprice (i.e., stock price) down through the floorboards during the post-Christmas computer-sales holocaust. The Italian company Olivetti rescued Acorn and now has a majority shareholding. Informed rumor contends that the Olivetti people didn't know about the ARM project when the rescue was first launched; if that is true, they must have been pleased when they found out.

In ARM, Acorn/Olivetti has one of the first commercial RISC processors in the world and an exceptionally able one. ARM could revolutionize the performance of even modestly priced home computers. It represents a striking vindication of the RISC philosophy in terms of performance, the time it took to develop, and its ease and low manufacturing cost.

Regular readers of this column may have noticed that I'm a bit of a nut for RISC processors, and it's a source of some vicarious pride to me that by the time you read this column, three powerful examples of the breed, all designed in Britain, will be available. In addition to Acorn's ARM announcement, the INMOS Transputer was launched on October 1, 1985, and the first Metaforth MF16LP has been delivered. ■



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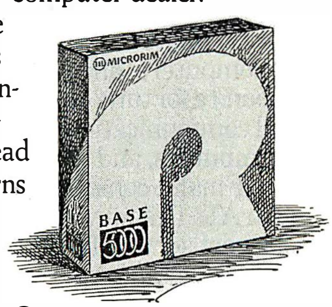
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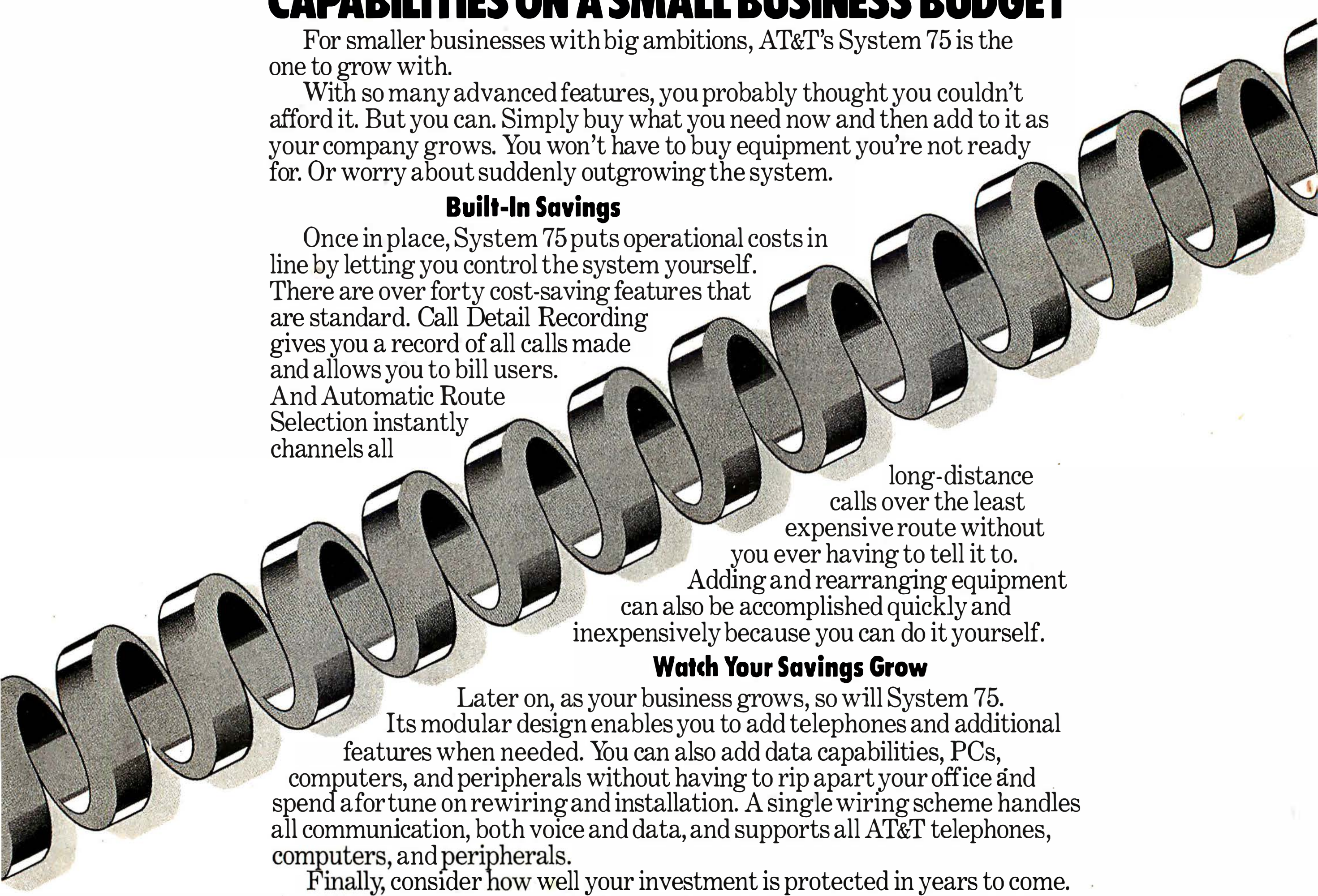
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Euclid's Algorithm

GCDs, LCMs, and repeating decimals

BY ROBERT T. KUROSAKA

In my last installment in November, I examined fractions that form repeating decimals. This month, I am going the other way and will look at how to represent repeating decimals as fractions. I concluded the November column with a presentation of the algorithm for converting repeating decimals to fractions. This month's column will include a program to implement that algorithm, which is shown in figure 1.

The most irritating part of the algorithm is step 5, reducing the fraction to lowest terms. Just how do we do that? First, we must find a common divisor, an integer that divides into both the numerator and the denominator. (For this column, "divides into" also implies "without remainder.") Although 24/30 can be reduced to 12/15 by dividing the numerator and denominator by 2, we must reduce again to 4/5 by dividing through by 3. However, I'm sure we all saw that the greatest common divisor (GCD) was 6 and reduced the fraction in one step. As the numerator and denominator get larger, it becomes more difficult to determine what divides into them.

There are a surprisingly large number of folkways for finding divisors of large numbers. Everyone knows that a number is divisible by 2 if its last (rightmost) digit is divisible by 2. A number is divisible by 4 if the last two digits are divisible by 4. For example, 7536 is divisible by 4 since 36 is divisible by 4. This basic pattern can be extended to higher powers of 2: A number is divisible by 8 if its last three digits form a number divisible by 8, and so on.

Similarly, we all know that a number is divisible by 5 if it ends in 0 or 5. A number is divisible by 25 if its last two digits are divisible by 25, by 125 if the final three-digit number is divisible by 125, etc.

As I mentioned in the last column, 2 and 5 are special cases in base 10, so it's not surprising that we can't generalize this to numbers other than powers of 2 and 5. However, there are some methods for other numbers. I'll briefly run down the list of techniques for other numbers up to 9.

A number is divisible by 3 if the sum of its digits is divisible by 3. For example, 312,798 is divisible by 3 since 3+1+2+7+9+8=30. Further, it is divisible by 6 because any even number that is divisible by 3 is divisible by 6. A number is divisible by 9 if the sum of its digits is divisible by 9. Thus, 312,798 is not divisible by 9, but 312,795 is (3+1+2+7+9+5=27).

The test for divisibility by 7 is rather amusing: "Detach" the last digit and double it, then subtract the result from the rest of the number. If the answer is divisible by 7, the original number is divisible by 7. For example (not that this method needs any clarification), to test 378, we detach the 8 and double it, then subtract 16 from 37. Since the answer, 21, is divisible by 7, so is 378. Try a larger number, 33,929. Detach the 9, double it, and subtract from 3392, giving 3374. Now, is 3374 divisible by 7? You don't know? Apply the test to 3374. (Why is no one laughing?)

Before giving up on these strange tests, let's look at 11. The divisibility test for 11 is a bit complicated but rather impressive. Add every other (alternate) digit in the number; add the remaining digits; if the difference of the two sums is divisible by 11, the number is divisible by 11. In 9,370,845, the first sum is 9+7+8+5=29, and the second sum is 3+0+4=7. Since their difference, 22, is divisible by 11, the entire number is divisible by 11. Note also that the sum of all the digits is 36, which is divisible by 9, and that the number ends in 5. Hence, with simple eyeballing, you can be the hit of the party by announcing that 9,370,845 is divisible by 495 (11×9×5).

Similar to our last example, you can determine that a number is divisible by 100 by applying our rules for divisibility by 4 and 25. (What? You have an easier way?) Well, perhaps you're beginning to feel that we need a more general method for finding common divisors of fractions. Our first im-

(continued)

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1. Let x equal the decimal:	$x = 0.7363636\ldots$
2. Multiply the equation by $10^{\wedge}$ (# of digits in the cycle)	$100\,x = 73.6363636\ldots$
3. Subtract 1. from 2.	$99\,x = 72.9$
4. Solve for x	$x = 72.9/99 = 729/990$
5. Reduce the fraction	$x = 81/110$

Figure 1: *The steps in converting repeating decimals to fractions.*

(a)	(b)	(c)
1	10	3
1581) 1734	153) 1581	51) 153
1581	1530	153
153	51	0

Figure 2: *Step-by-step application of Euclid's algorithm to the problem of finding the greatest common divisor of* 1734 *and* 1581.

pulse is to use prime factorization. This is certainly a correct approach, but most prime-factorization subroutines are cumbersome or time-consuming. I will show you a delightfully direct method of finding the GCD of two numbers that is easily programmed and requires no guessing, no trial and error, and no prime factorization. This remarkable method is called Euclid's algorithm.

Let us reduce the fraction 1581/1734. The steps are

1. Divide the larger number by the smaller. In figure 2a, 1734/1581 = 1 with a remainder of 153.

2. If the remainder is not 0, divide the divisor by the remainder. In figure 2b, 1581/153 = 10 with a remainder of 51.

3. Repeat step 2 until a 0 remainder occurs. In figure 2c, 153/51 = 3 with a remainder of 0.

The last divisor is the GCD of the two numbers (most texts call it the last nonzero remainder). In figure 2c, the last divisor is 51. Therefore, the GCD of 1581 and 1734 is 51. And, sure enough, the fraction reduces to 31/34.

An obvious but necessary remark: If the GCD is 1, the two numbers are relatively prime; the fraction is already expressed in lowest terms.

Listing 1 offers a program that reduces a fraction to lowest terms by Euclid's algorithm. [*Editor's note: The Microsoft* BASIC *listings in this column are available for downloading from* BYTEnet *Listings at* (617) 861-9764.]

An annoyance related to reducing fractions arises when adding or subtracting fractions with unequal denominators. We need to find the least common denominator (LCD). Before finishing our cyclic decimal-to-reduced-fraction routine, let's take a side trip to shine some light on LCDs.

In 1/9 + 5/12, we see that the LCD is 36. But precisely what are we seeing?

(continued)

Listing 1: A BASIC *program using Euclid's algorithm to reduce a fraction to its lowest terms. The routine begins at line* 310 *so that, when listing* 3 *is merged with it, the unnecessary lines* (310 *to* 410) *are overwritten.*

```
310 '************************************************************************
320 '*                 EUCLID'S ALGORITHM FOR GREATEST COMMON DIVISORS                   *
330 '*                              BY ROBERT T. KUROSAKA                                *
340 '************************************************************************
350 CLS
360 PRINT "This program calculates the greatest common divisor"
370 PRINT "of a positive fraction"
380 PRINT "and reduces the fraction to lowest terms."
390 PRINT :PRINT
400 INPUT "ENTER THE FRACTION'S NUMERATOR";NUM:NUM = ABS(NUM)
410 INPUT "ENTER THE FRACTION'S DENOMINATOR";DEN:DEN = ABS(DEN)
420 DIVISOR = NUM:DIVIDEND = DEN 'SAVE ORIGINAL VALUES FOR LATER DISPLAY
430 REM IF EITHER TERM IS NOT A WHOLE NUMBER, CLEAR THE DECIMAL.
440 IF DIVISOR< >INT(DIVISOR) OR DIVIDEND< >INT(DIVIDEND) THEN DIVISOR = DIVISOR*10:
       DIVIDEND = DIVIDEND*10:NUM = DIVISOR:DEN = DIVIDEND:GOTO 440
450 IF DIVISOR>DIVIDEND THEN SWAP DIVISOR, DIVIDEND
460 WHILE DIVISOR>0
470        QUOTIENT = INT(DIVIDEND/DIVISOR)
480        REMAINDER = DIVIDEND - DIVISOR*QUOTIENT
490        DIVIDEND = DIVISOR:DIVISOR = REMAINDER
500 WEND
510 PRINT :PRINT
520 PRINT "THE FRACTION ";NUM;"/";DEN;" HAS A GCD OF ";DIVIDEND
530 IF DIVIDEND = 1 THEN PRINT "THE FRACTION IS ALREADY IN LOWEST TERMS.":GOTO
    560
540 PRINT "THE REDUCED FRACTION IS: ";NUM/DIVIDEND;" /";DEN/DIVIDEND;
550 IF DEN/DIVIDEND = 1 THEN PRINT " = ";NUM/DIVIDEND
560 END
```

The LCD is the smallest integer that is evenly divisible by both denominators. To put it another way, the LCD is the least common multiple (LCM) of the denominators. While any common multiple of 9 and 12 will suffice for adding the fractions (e.g., their product, 108), we prefer the least value because it will simplify reducing the fraction later.

(a)		(b)		(c)		(d)	
	3 6 8		1 2 8		1 1 4		1 1 1
3	9 18 24	3	3 6 8	2	1 2 8	4	1 1 4

Figure 3: *Finding the least common multiple of three numbers using triple division.*

With larger denominators, the task of finding the LCD becomes increasingly difficult. In 5/12 and 3/14, it is not easily seen that the LCD is 84. Many methods have been devised for finding the LCD, most of which require prime factorization. One rather mystical method works for any number of denominators.

Suppose we want the LCM of 9, 18, and 24. Find a common divisor for all three numbers, if possible. If not, find a common divisor for any two of them, if possible. (If not, the numbers are relatively prime; the LCM is merely the product of the three numbers.)

Listing 2: A BASIC *program to find the least common multiple of a set of numbers using Euclid's algorithm.*

```
10 '*************************************************************************
20 '*                    LEAST COMMON MULTIPLE ALGORITHM                    *
30 '*                         BY ROBERT T. KUROSAKA                         *
40 '*************************************************************************
50 CLS
60 PRINT "This program calculates the least common multiple"
70 PRINT "of a set of positive integers."
80 PRINT
90 INPUT "HOW MANY INTEGERS ARE IN THE SET";TERMS:TERMS=INT(ABS(TERMS))
100 IF TERMS<2 THEN 400
110 REM NUMBER ARRAY HOLDS THE SET OF INTEGERS FOR WHICH THE LCM IS SOUGHT.
120 DIM NUMBER(TERMS)
130 PRINT :PRINT "ENTER THE INTEGERS ONE AT A TIME."
140 FOR I=1 TO TERMS
150       INPUT NUMBER(I)
160       NUMBER(I)=INT(ABS(NUMBER(I)))
170       IF NUMBER(I)=0 THEN PRINT "ILLEGAL ENTRY.":GOTO 150
180 NEXT I
190 REM BEGIN LCM PROCEDURE.
200 LCM=NUMBER(1)        'THE LCM OF A SINGLE NUMBER IS ITSELF.
210 FOR I=2 TO TERMS
220       REM FIND GCD OF ACTIVE ENTRY AND WHAT PRECEDED IT (GCD WILL BE STORED
             IN 'DIVIDEND' BECAUSE LINE 290 ASSIGNS LAST VALID DIVISOR TO DIVIDEND).
230       DIVISOR=NUMBER(I):DIVIDEND=LCM
240       REM LINES 250-300 ARE THE SAME AS 450-500 OF THE GCD ROUTINE.
250       IF DIVISOR>DIVIDEND THEN SWAP DIVISOR,DIVIDEND
260       WHILE DIVISOR>0
270             QUOTIENT=INT(DIVIDEND/DIVISOR)
280             REMAINDER=DIVIDEND-DIVISOR*QUOTIENT
290             DIVIDEND=DIVISOR:DIVISOR=REMAINDER
300       WEND
310       LCM=NUMBER(I)*LCM/DIVIDEND
320       REM THE LAST LCM WILL BE LCM OF ALL THE ENTRIES.
330 NEXT I
340 PRINT :PRINT
350 PRINT "THE LEAST COMMON MULTIPLE OF";
360 FOR I=1 TO TERMS
370       PRINT NUMBER(I);
380 NEXT I
390 PRINT "IS";LCM
400 END
```

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We will perform a triple division on these three numbers. In figure 3a, we divide the common divisor 3 into all three numbers. Note that we did not divide the first two numbers by 9 because our precedence of rules requires us to first look for divisors of all the numbers.

Next, we repeat the procedure for the three quotients: 3, 6, and 8. The first two are divisible by 3 again (figure 3b). Important: If the divisor does not divide into a particular number, merely *copy* the number. In figure 3b, the 8 is brought up. This procedure is repeated until all the quotients are 1s. In figure 3c, the 2 and 8 are divided by 2, with the 1 being brought up. Finally, in figure 3d, we divide by 4 and obtain all 1s in the quotients. The LCM is the product of all the divisors used. That is, the LCM of 9, 18, and 24 is $3 \times 3 \times 2 \times 4 = 72$.

You might enjoy trying to write a program to implement this method. There is, however, yet another method for finding the LCM, and, not surprisingly, it employs Euclid's algorithm.

The LCM of two numbers *a* and *b* is the product of the numbers divided by their GCD. That is, $\text{LCM}(a,b) = a \times b / \text{GCD}(a,b)$. This becomes apparent if we look at a simple example: 10 and 14. Their product, 140, is a multiple, but it isn't the smallest one. Since $10 = 2 \times 5$ and $14 = 2 \times 7$, their LCM needs only $2 \times 5 \times 7$, while their product is $2 \times 5 \times 2 \times 7$. Dividing by their GCD of 2 eliminates the overlap. In the language of elementary set theory, the LCM is the union of the two sets of factors. The formula above instructs us to "add" the two sets together and then "subtract" their intersection.

Since we already have the GCD program, we are only one step away from finding the LCM of two numbers. That's the good news. The bad news is that this method works only with two numbers at a time. To find the LCM of three or more numbers (say, 8, 10, and 14), we first find the LCM of 8 and 10 (40) and then find the LCM of 40 and 14 (280). This is no problem for a computer, but you may feel that it is less efficient than our triple-division approach. Anyway, listing 2 presents my version of the LCM routine using Euclid's algorithm.

I use strings, of course, because you can't directly enter a repeating decimal into the computer.

Finally, we are ready to return to our initial problem of converting a repeating decimal to a fraction. Listing 3 shows my routine for doing steps 1 through 4 of figure 1. The program is mostly a lot of string-handling. I use strings, of course, because you can't directly enter a repeating decimal into the computer. So I use a "__" to signify where the cyclic part begins and enter the number through one iteration of the cycle. This is analogous to the way of writing repeating decimals like 0.333. . . as $0.\overline{3}$. Not only are you unable to enter repeating decimals into the computer, the computer is unable to hold any infinite series. However, the point of step 3 is to get rid of the cyclic part. All of the action in the method happens in the nonrepeating part and the first iteration of the cycle. So that is all that we use in our program.

The only really interesting part of this routine is in line 420. After I find the value of the unreduced fraction's numerator and denominator, I convert the values into strings and then back to numbers. Why?

When I first tried writing the routine in listing 3, I used the number $0.7\overline{36}$ as one of my test cases. The routine displayed the numerator value as 72.9 and the denominator value as 99. However, when I merged the routine with listing 1, I got strange results. It seems that Microsoft BASIC's guard digits were nonzero, so when the GCD routine tried to clear the decimal from the 72.9, the fraction became 7.29×

(continued)

Listing 3: A BASIC *program to convert a cyclic decimal number into an unreduced fraction. You can merge this program with listing* 1 *to make a complete implementation of the algorithm in figure* 1.

```
10 '**************************************************************************
20 '*                REPEATING DECIMAL TO FRACTION CONVERTING ROUTINE        *
30 '*                          BY ROBERT T. KUROSAKA                         *
40 '**************************************************************************
50 CLS
60 PRINT "This routine can be used with the greatest common denominator"
70 PRINT "program. Load the GCD program, then MERGE this routine into it."
80 PRINT "The MERGEd program is designed to determine the reduced fractional"
90 PRINT "representation of a repeating decimal.":PRINT
100 PRINT "To ENTER a repeating decimal:":
    PRINT " Type the nonrepeating part, then a '_' before the cycle."
110 PRINT "For example, 1.2_345 is the proper entry for 1.2345345345. . . "
120 PRINT "The decimal should always precede the '_', i.e., .333. . . . is entered":
    PRINT "as '._3'. Reversing the '.' and '_' will cause an error.":PRINT
130 INPUT "ENTER REPEATING DECIMAL";NUMBER$
140 REM NONREPEATING PART OF NUMBER IS THAT PART UP TO "_". VAL OPERATOR
        IGNORES ALL NUMBERS AFTER A NONNUMERICAL CHARACTER. THUS, IN
        1.2_345,VAL("1.2_345") WILL BE 1.2, ETC.
150 NONREPEATING.PART=ABS(VAL(NUMBER$))
160 REM DEFINE A MORE READABLE FUNCTION TO USE FOR THROWING THE LEFTMOST
        CHARACTER OF A STRING AWAY.
170 DEF FNDROP.LEFT$(A$)=RIGHT$(A$,LEN(A$)-1)
180 REM FIND DECIMAL POINT
190 WHILE LEFT$(NUMBER$,1) <> "."
200     NUMBER$=FNDROP.LEFT$(NUMBER$)
210 WEND
220 NUMBER$=FNDROP.LEFT$(NUMBER$)
230 REM FIND OUT HOW MANY DECIMAL PLACES THE REPEATING CYCLE IS OFFSET FROM
        THE DECIMAL POINT.
240 WHILE LEFT$(NUMBER$,1) <> "_"
250     OFFSET=OFFSET+1
260     NUMBER$=FNDROP.LEFT$(NUMBER$)
270 WEND
280 REM THROW AWAY REPEATING PORTION MARKER, "_"
290 NUMBER$=FNDROP.LEFT$(NUMBER$)
300 REM HOW MANY DECIMAL PLACES ARE IN THE CYCLE? SINCE THE REPEATING CYCLE
        IS EVALUATED AFTER THROWING AWAY THE DECIMAL POINT, MULTIPLY BY
        10^-(TOTAL NUMBER OF PLACES TO THE RIGHT IT SHOULD BE SHIFTED).
310 CYCLE.LENGTH=LEN(NUMBER$)
320 REPEATING.CYCLE=VAL(NUMBER$)*10^-(OFFSET+CYCLE.LENGTH)
330 REM NUMBER=NONREPEATING PART+REPEATING CYCLE. SINCE THE FIRST
        ITERATION OF THE CYCLE IS THE ONLY ONE THAT DOES NOT CANCEL ON
        SUBTRACTION, ONLY USE IT.
340 NUMBER=NONREPEATING.PART+REPEATING.CYCLE
350 REM "CLEARED.NUMBER IS THE VALUE OF THE SUBTRACTION THAT DOES AWAY WITH
        THE INFINITE CYCLE (STEP 3 IN THE BYTE ARTICLE ALGORITHM).
360 CLEARED.NUMBER=NUMBER*10^CYCLE.LENGTH-NONREPEATING.PART
370 REM NOW, ASSIGN THE VALUES OF THE NUMERATOR AND DENOMINATOR TO THE
        VARIABLE NAMES USED IN THE GCD ROUTINE.
380 NUM=CLEARED.NUMBER:DEN=10^CYCLE.LENGTH-1
390 REM I CONVERT NUM AND DEN TO STRINGS AND THEN BACK TO CLEAR THE GUARD
        DIGITS IN THE NUM AND DEN VARIABLES. SEE BYTE ARTICLE FOR DETAILS.
400 NUM$=STR$(NUM):DEN$=STR$(DEN):NUM=VAL(NUM$):DEN=VAL(DEN$)
410 PRINT "THE EQUIVALENT UNREDUCED FRACTION IS:";NUM;"/";DEN
```

10^7 before the decimal-clearing routine gave up in disgust. By converting the values calculated in listing 3 to string values, I clear the guard-digit garbage out of the numerical representation. When I then reconvert the values into numbers, the GCD routine functions properly.

As always, I welcome your comments, criticisms, and suggestions. I've been getting some interesting mail on previous columns and will devote some space in an upcoming column to some of the more interesting insights. ■

C·I·R·C·U·I·T C·E·L·L·A·R F·E·E·D·B·A·C·K

Conducted by Steve Ciarcia

MUSEUM CONTROL

Dear Steve,

I have used the BSR X-10 system to control a museum exhibit. One problem I encountered, which an engineer at BSR confirmed, was that the lamp modules would not properly control low-wattage light bulbs (25 watts or less). Do you have any ideas about how I can get around this problem cheaply?

Also, what happens if two controllers send commands at the same time? For example, controller *x* sends an ON command to unit A3 at the same time controller *y* sends an OFF command to unit B2. Wouldn't a hopelessly jumbled signal result?

TIMOTHY S. GOODFELLOW
Raleigh, NC

Your letter does not state what problems you experienced with lamp modules controlling low-wattage bulbs, so it is hard to give you an exact answer. During development of the Home Run Control System (April through June 1985), I did a lot of testing using a 7-watt nightlight, and the lamp modules were able to turn it on, off, and dim it correctly. Perhaps BSR has improved the modules since you experienced the problem. One solution would be to use higher-wattage bulbs and dim them to the level that you want. (The Home Run system can do this for you automatically.)

You are quite right that two BSR controllers transmitting simultaneously would result in a jumbled signal. The BSR works by sending bursts of 120 kHz at 2.778-millisecond intervals in a pattern that the modules decode. (See my article in the May 1985 BYTE for details on BSR operation.) If a second controller starts transmitting after the first has started, the timing between the pulses would be altered, and the modules would not be able to decode the signal.—Steve

LOOKING FOR A UART

Dear Steve,

I am an electronics student who is planning to build a scrolling LED display similar to your April 1984 project.

I plan to use my 8085 minisystem with 2K bytes of EPROM and 1K byte of RAM. The user will be able to enter messages through an ASCII keyboard. Could you please let me know where I can purchase an inexpensive UART, so that the message is transmitted serially to the display?

Also, would the Hewlett-Packard "union jack 1-inch" 16-character display be more cost-efficient and less complex to build than the one in your project?

MICHAEL SARRETT
San Francisco, CA

You can purchase a UART from most of the mail-order electronics supply houses. The Intersil IM6402IPL costs $6.90 as Digi-Key part number NT5000-ND. Order from

Digi-Key Corporation
Highway 32 South
POB 677
Thief River Falls, MN 56701
(800) 346-5144

Any common-anode dot-matrix LED display can be used in place of the single LEDs used in my project as long as it has a sufficient dot matrix (5 dots per row by 7 dots per column). The electronics can be modified to handle larger or smaller LED matrices.—Steve

PARALLEL PROCESSING

Dear Steve,

In your article "Build the Microvox Text-to-Speech Synthesizer" (September and October 1982), you stated that the more sophisticated text-to-speech programs required up to 80K bytes of memory, half of which contains words that are exceptions to the rules. It has occurred to me that if such a program were implemented on a single microprocessor, even a fast and powerful one, the time required to generate speech would be prohibitive. Would it be possible to run several processors in parallel, one containing the rules and several others containing words that are exceptions to the rules?

Also, in "The Lis'ner 1000" (November 1984), the caption for photo 4 states that 64 concurrent available words form a reasonable search vocabulary. Are more possible? If not, could parallel processing be used to overcome this problem?

ALAN ADEN
Camp Point, IL

Parallel processing is the wave of the future. Supercomputers are rapidly approaching the upper limit of speed for a single processor, and the only way to solve a problem any faster is to put several processors to work on the problem in parallel. The way to accomplish this in the manner you suggest is feasible but may not gain much speed. Looking up an item in a sorted table can be done rapidly by using a binary search and even faster if a technique called hashing is used. A table having 8000 entries would require 13 tests to find the desired word. Splitting the table in half and putting each half on a separate processor would reduce the number of tests to 12 on each processor—not much of a gain. The greatest gain would be to have one processor performing a text-to-speech algorithm while a second one searches for the word. If the word is found in the search, the text-to-speech algorithm would be stopped and the word from the table fed into the synthesizer.

Your second idea of applying parallel processors to speech recognition could increase the number of words it could recognize almost linearly with the number of processors you have working on the input word. The only problem you might encounter would be when two or more processors think they have a match, and another processor would have to pick one of the candidates.—Steve ■

Over the years I have presented many different projects in BYTE. I know many of you have built them and are making use of them in many ways.

I am interested in hearing from any of you telling me what you've done with these projects or how you may have been influenced by the basic ideas. Write me at Circuit Cellar Feedback, POB 582, Glastonbury, CT 06033, and fill me in on your applications. All letters and photographs become the property of Steve Ciarcia and cannot be returned.

Ordering Disks of BYTE Listings

Source-code listings in the form of text files of programs that accompany BYTE articles are now available from BYTE on disk. To order a disk of these listings for noncommercial purposes, indicate the issue (the first available is December 1985) and the kind of disk below. Enclose a check or money order in the correct amount made out to BYTE Listings. All prices include postage.

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(all cost $5 per disk in North America, $6 in Europe and South America, $7 in Asia, Africa, and Australia)

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- ☐ Apple II 5¼-inch DOS 3.3
- ☐ Apple II 5¼-inch ProDOS
- ☐ Commodore 64
- ☐ Hewlett-Packard 125
- ☐ Kaypro 2 CP/M
- ☐ TRS-80 Model III
- ☐ TRS-80 Model 4
- ☐ Texas Instruments Professional
- ☐ Zenith Z-100
- ☐ Atari

COMMON 3½-inch FORMATS
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Bulletin Boards in Canada

Listed below are some Canadian computer bulletin boards that will carry program listings from BYTE. Programs are for noncommercial use in connection with BYTE articles only. There are no usage charges but you must pay your own telephone charges.

Western Canadian Distribution Center (101 11112 101st St., Edmonton, Alberta, T5G 2A2) will be supplying listings to its member bulletin-board systems.

Canadian Remote Systems, Toronto, Ontario, (416) 231-9202

Edmonton, Alberta, (403) 454-6093

Meadowlark, Alberta, (403) 435-6579

Prince George, British Columbia, (604) 562-9519

Regina, Saskatchewan, (306) 586-5585

Winnipeg, Manitoba, (204) 452-5529

In addition, BYTEnet Listings are available from or arrangements are being made with one or more system operators in the following nations: Australia, Canada, Chile, Denmark, France, Hong Kong, Ireland, Italy, Japan, Norway, Singapore, United Kingdom, Uruguay, and West Germany. Contact us at (603) 924-9281 for an up-to-date list.

(continued from page 32)

Intel has adhered to two of the unwritten rules of benchmarking. It used benchmarks developed outside Intel and contracted an outside company to run the benchmarks on its machines. What Intel did not do is have the results interpreted by an objective, independent party.

Intel did contact me prior to publication of the report, but only for permission to reprint the listings (which the company trimmed the comments out of) and not in an advisory capacity. I gave the company reprint permission. I expected that the benchmarks would be used carefully and according to the guidelines of my article. Clearly, Intel could have avoided the problems mentioned above if it had had an outside independent party evaluate its benchmarking methodology and its interpretation of results. At first, I was upset that Intel did not reference me as author of the BYTE benchmarks. Upon reflection, I am glad it did not.

David Hinnant
Research Triangle Park, NC

Positioning Printer Paper

Part of my job as an electronics technician requires me to make considerable use of computers and printers. Additionally, I am the owner of a personal computer. Something that I (and I'm sure, many others) have noticed is how difficult it is to get the paper positioned "just so" when first loading it into the printer, so that the printer doesn't print on the perforations, the spacing is right from top to bottom, etc. I think I may have a solution to the problem, which I would like to suggest to the printer and paper/forms manufacturers.

My suggestion is that the printer makers get together with the manufacturers of paper and forms and devise/implement a method for advancing paper/forms to the top of the sheet. I'm aware that some printers have a top-of-form function, but this is usually a variant of a formfeed. What I propose is a method of advancing the paper until the first *printable* line is under the print head, regardless of sheet size or position.

I've given the matter quite some thought, and I think that this could be implemented fairly easily by using the following scheme.

During the manufacturing process for the paper, a dark band or spot would be printed on the paper (between feed holes) some distance from the top of the sheet. This should be fairly easy to do since most paper I've seen has the manufacturer's name already printed on it, and this band or spot would be easily added.

Then, on the printers, a sensor (possibly an MCA-7 optical sensor) would be placed in such a position as to detect that dark band/spot when the first printable line is under the print head. Judging from the number of printers I've seen, this would probably be located in the area immediately under the platen of the printer, perhaps two or three inches lower than the print head. Such a distance would allow the use of full-sized paper, as well as formfeed checks, etc.

By using such a technique, when a top-of-form button was pressed (or command issued) the paper would advance appropriately and stop. Such a system might even prove to be a replacement for the more traditional formfeed command/button, since it would *reliably* position the paper/form every time (regardless of sheet size), even after paper/form changes or completely powering down the printer.

I would be happy to hear any comments, suggestions, and criticisms BYTE readers might have about this idea.

David K. Merriman
Fullerton, CA ■

NEW SYSTEMS

PC-Compatible Kaypro

The Kaypro PC is an MS-DOS machine based on a 4.77-MHz Intel 8088 microprocessor, with a socket for the Intel 8087 math coprocessor. It comes with 256K bytes of RAM, expandable to 640K bytes, two double-density 360K-byte floppy-disk drives, and room for either a full- or half-height hard-disk drive. Its multivideo adapter supports monochrome, color graphics, and composite video output. System boards use three of the nine IBM PC-compatible expansion slots, leaving the user with three full-length and three half-length slots. Its 132-watt power supply can support a hard disk. It has both serial and parallel ports.

The Kaypro PC comes with a 12-inch monochrome monitor and an IBM Selectric–style detachable keyboard with the same layout as the Kaypro 286i and PC AT keyboards.

Kaypro is bundling MS-DOS 2.11, WordStar, Mailmerge, CorrectStar, StarIndex, MITE, Polywindows/KDESK, and GW-BASIC with the system. It costs $1595. Contact Kaypro Corp., 533 Stevens Ave., Solana Beach, CA 92075, (619) 481-4300.
Inquiry 565.



The Kaypro PC.

Single-Board VS-186

Virtual Systems' VS-186 is a PC-DOS–compatible, single-board computer that can accept up to 512K bytes of ROM and up to 1-megabyte of parity-checked RAM. The 8½- by 11-inch computer board is aimed at the measurement and control market and therefore is self-contained and built to work in extreme industrial environments.

Standard operating systems for the VS-186 are PC-DOS, C/PM-86, and Virtual Systems' UNIX-style QNX.

The VS-186 is founded on an 8-MHz 80186 microprocessor and contains a socket for an 8087 math coprocessor. ROMs can be installed in six EPROM sites; two other ROM sites are occupied by the system code. The VS-186 comes with 256K of parity-checked RAM controlled by an 8208 memory controller chip and arranged as two banks, yielding a no-wait-state system that lets the 80186 run at full speed.

The VS-186 has two RS-232C serial ports, a programmable parallel port, a Centronics-compatible parallel port, a SASI/SCSI interface for disk and tape drives, and a processor-bus extension. The serial ports are controlled by a dual serial-channel controller and can operate asynchronously or synchronously. Four iSBX expansion connectors are wired to the 80186's DMA channels for high-speed I/O.

The VS-186's price is $950. Contact Virtual Systems, Suite 406, 1500 Newell Ave., Walnut Creek, CA 94596, (415) 935-4944.
Inquiry 566.

128K Color-Graphics Single-Board Quark/150

The Megatel Quark/150 is a color-graphics single-board computer based on the Z80B microprocessor. It includes a 128K-byte dynamic RAM, two serial ports, four parallel ports, a floppy-disk controller, and RGB video output. The floppy-disk controller can handle up to four drives of any size in any combination.

The RGB interface can be configured 16 different ways using three resolution modes: 2 colors at 640 by by 240, or 16 colors at 160 by 240. A graphics software package with 27 (TeleVideo TPC I-compatible) functions gives you eight fill patterns, eight line styles, multiple character heights and widths, ellipse and arc functions and lets you change the resolution mode for any line.

The Quark/150 is a 4- by 6-inch Eurocard. It comes with CP/M 2.2 BIOS, the Megatel graphics primitives, and a transition board that provides an interface to standard peripherals for $695. Contact Megatel Computer Technologies, 2311 South Anthony Blvd., Fort Wayne, IN 46803, or call (416) 745-7214.
Inquiry 567.

XT-Compatible GMS PC/286

The IBM PC XT-compatible Gulfstream Micro Systems Professional Computer/286 has an 80286 microprocessor running at 8 MHz with zero wait states. An 80287 numeric coprocessor is optional. The system comes with 256K bytes of on-board memory, expandable to 640K on the motherboard, and eight expansion slots. Video boards, ports, and monitors are not provided.

The system is sold in three model groups. The first group consists of computers with one or two 360K-byte floppy-disk drives. Model Group 2 adds the choice of a 10-, 20-, or 30-megabyte hard disk. Model Group 3 adds a 10- or 60-megabyte internal tape backup.

Prices for Model Group 1 start at $2995; for Model Group 2, $4420; for Model Group 3, $5388. Contact Gulfstream Micro Systems, 5500 North Federal Highway, Boca Raton, FL 33431, (305) 994-6500.
Inquiry 568.

PERIPHERALS

Eight-Pen Color Plotter from HP

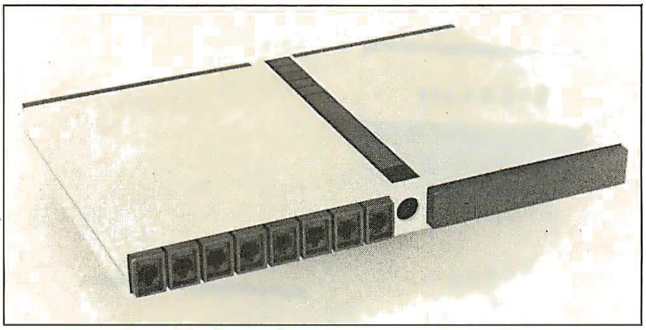
Hewlett-Packard's ColorPro is an eight-pen plotter that can produce multicolor pie, bar, and line graphs and text charts on 8½- by 11-inch paper or on overhead-projector transparencies. Its high resolution of 0.001 inch is said to give it a fine-line quality as much as four times better than comparable plotters. Such resolution improves the drawing of both straight lines and solid fills.

The ColorPro moves pens at 15.7 inches per second. You can select pens from the carousel through software or front-panel commands. Pens in the carousel are automatically capped. HP offers pens in two widths and 10 colors for paper. Transparency pens are available in seven colors.

A slot for ROM cartridges lets you expand or customize the ColorPro's capabilities. An HP graphics-enhancement cartridge adds a larger buffer and more advanced graphics commands.

Lotus's 1-2-3 and Symphony, Decision Resources' Chart-Master and Sign-Master, and HP's Graphics Gallery and Textcharts are some of the programs that work with the ColorPro. The HP-GL programming language is built into the plotter.

Available with an RS-232C or an IEEE-488 interface, the ColorPro costs $1295 and works with HP, IBM, Apple, Compaq, and most other personal computers. The graphics-enhancement cartridge costs $195. Contact Hewlett-Packard, Inquiries Manager, 1820 Embarcadero Rd., Palo Alto, CA 94303.
Inquiry 569.



Matrix's Alliance cluster controller.

2400-bps Modem from UDS

Universal Data Systems' FasTalk 2400 is a Hayes-compatible modem that connects to your personal computer via the RS-232C port. It uses V.22 and V.22bis asynchronous modulation for full-duplex operation at 2400 bps over public switched telephone networks. It will also work as a Bell 212A or 103 series modem at 1200 or 300 bps.

FasTalk 2400 comes with an asynchronous communications package called SignOn for IBM and compatible personal computers. SignOn stores up to 100 phone numbers in a directory and dials any one of them with a single keystroke. You can store automatic log-on sequences, and you can set dates and times for unattended data transfer.

The FasTalk 2400 modem and SignOn cost $625. Contact Universal Data Systems, 5000 Bradford Dr., Huntsville, AL 35805, (205) 837-8100.
Inquiry 570.

RS-232C Networking with Alliance

The Alliance cluster controller allows networking of 2 to 20 IBM PCs and peripherals using standard RS-232C serial ports and proprietary software. The basic Alliance controller includes a Hitachi 64180 (an enhanced Z80-compatible) microprocessor, software both in the Alliance and for each PC on the network, and eight serial ports; additional modules with four ports each can be added. An optional 480K-byte printer buffer can also be installed, as can a serial-to-parallel converter. Information is transferred through the network at 115K bits per second, which is relatively slow compared to other PC networks.

The basic eight-port Alliance should be available this month for a list price of $895. Each four-port expansion module is $349. Contact Matrix Communications, 112–116 Washington St., Marblehead, MA 01945, (617) 639-1211.
Inquiry 571.

RAM Box for Macintosh

MacVentures' QuickDrive is an external RAM-disk box that works with the Apple Macintosh. The basic QuickDrive contains 510K bytes of RAM that is designed to behave like a fast disk drive. You can get more RAM with the 1-, 1.5-, or 2-megabyte versions of the device or by adding up to three 510K-byte expansion modules to the basic QuickDrive box.

You connect QuickDrive to the printer port or, for AppleTalk users, the modem port. You can then attach your printer to a second port on the QuickDrive. QuickDrive has its own switching power supply, which will accept 12 volts AC or DC, and a connector to tap standard wall voltage. Because QuickDrive doesn't depend on the Mac for power, it retains any information on the RAM disk even if the Mac accidently loses power or is turned off. You don't have to modify the Macintosh hardware in any way to use QuickDrive.

QuickDrive does not use any of the Macintosh's memory space. MacVentures claims that it is five to ten times faster than floppy-disk drives because its data-transfer rate is greater than 900 kbps. It also claims QuickDrive can launch MacWrite in 7.4 seconds and MacPaint in 5.1 seconds.

QuickDrive comes with a menu-driven program that lets you configure the size and number of disk volumes you want to use and lets you set up a print spooler that can handle printing as a background task.

The basic QuickDrive costs $499, has a 90-day warranty, and includes 510K of RAM, a printer port, a cable, a power supply, and the controlling software. The 1-megabyte, 1.5-megabyte, and 2-megabyte versions of QuickDrive cost $649, $799, and $949, respectively. The 510K-byte expansion modules cost $169 each. Contact MacVentures, POB 6123, Aloha, OR 97007, (503) 645-9696.
Inquiry 572.

(continued)

ADD-INS

10-MHz 80286 Board for IBM PC

Applied Reasoning's PC-elevATor Model 2100 allows the IBM PC to operate at up to twice the speed of IBM's PC AT, by adding an 80286 microprocessor running at 10 MHz with no wait states. An optional 5- or 8-MHz 80287 floating-point coprocessor can also be added to the card to speed up computation-intensive programs. The card also has 1 megabyte of memory.

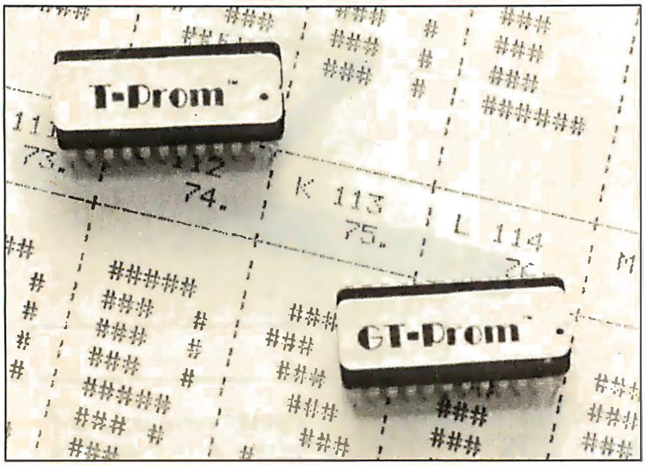
The PC-elevATor is priced at $2695. For more information, contact Applied Reasoning, 765 Concord Ave., Cambridge, MA 02138, (617) 492-0700.
Inquiry 573.

Hardware-assisted Bug Zapper

The Bug Zapper is a hardware-assisted debugging tool for the IBM PC. The IBM PC half-slot expansion card provides a "zap" circuit that monitors memory addressing and interrupts a program when it overwrites specified locations, enabling the programmer to search through memory to find out where the program went off track. Also available at all times is a "halt" button, which interrupts program execution even when normal interrupts have been disabled, also allowing registers and memory to be checked to locate the cause of unwanted behavior.

Guardian, the monitor program included with the Bug Zapper, is installed at boot time; the halt and zap functions both turn control over to the Guardian monitor or optionally to another host debugging program such as Microsoft's SYMDEB. Guardian performs standard debugging functions including view or overwrite memory or registers, port input or output, trace, and unassemble.

The Bug Zapper, with both the expansion card and Guardian, is priced at $195. For more information, contact Microtech International, 9906 Norwood Court, Dept. M-3, Largo, MD 20772, (301) 350-1068.
Inquiry 574.



Norcom chips for enhanced text.

Enhanced Text Mode for Heath/Zenith 89 and 19

The T-Prom character-generator chip from Norcom provides an enhanced character set for the Heath/Zenith 89, 89A, 19, and 19A computers. The replacement character ROM chip enhances 94 text characters, while maintaining graphics compatibility by not changing any of the graphics characters. Another chip, the GT-Prom, combines the T-Prom features with the graphics enhancements of Norcom's earlier G-Prom on a single chip.

The T-Prom chip is priced at $19.95; the GT-Prom is $24.95. For more information, contact Norcom, 9630 Hayes, Overland Park, KS 66212, (913) 888-6237.
Inquiry 575.

Breadboards for Eurocard, PC Buses

Augat has added two breadboards to its Unilayer II product line. The company is now offering a 220-mm dual Eurocard and an IBM PC AT-compatible board.

The Eurocard has a high-density universal pattern and will accommodate up to 150 16-pin DIP equivalents. It has a primary I/O connector, two 96-pin DIN connectors, and an I/O header that supports two 64-pin DIN connectors.

The IBM PC AT-compatible board also has a high-density universal pattern and will accommodate 94 16-pin DIP equivalents. The I/O supports the IBM PC AT-compatible edge connector, a 37-pin D-subminiature, and a 50-pin header area.

Augat will wire the boards for you if you transmit the wiring data to Augat electronically; wired boards can be delivered within four weeks. Unwired, the Eurocards cost $220 apiece or $1505 for 10. The AT-compatible boards cost $197 each or $1590 for 10. Contact Augat Inc., Systems Division, 40 Perry Ave., POB 1037, Attleboro, MA 02703, (617) 222-2202.
Inquiry 576.

ImageMate Emulation Card

Orange Micro's ImageMate card enables Apple's Imagewriter II printer to emulate an Epson FX-80 or IBM Graphics Printer, while also adding a printer buffer with 64K bytes of memory (expandable to 128K). The ImageMate also includes an adapter cable and DIP switches to select IBM or Epson emulation.

For Apple computer owners who don't need Epson or IBM emulation, Orange Micro announced a similar card that adds an intelligent printer buffer to the Imagewriter II. The ImageBuffer card adds 64K or 128K bytes of buffer memory and can also print multiple copies of buffered documents. A clear-buffer feature is also provided to eliminate the need to power-off the printer when unwanted information is in the buffer.

Both ImageWare expansion cards will retail for approximately $120 each. Contact Orange Micro, 1400 North Lakeview Ave., Anaheim, CA 92807, (714) 779-2772.
Inquiry 577.

SOFTWARE • APPLE

Modeling in Three Dimensions

MacModel is a solids modeler for the Macintosh that lets you draw three-dimensional objects and view them from many vantage points in wide-angle or telephoto perspective. You can create models of objects as small as molecules or as large as tall buildings.

The software handles constructive solid geometry. You can start with basic objects like spheres and cubes, then combine them with union, intersection, or subtraction to form any object. Also, you can move, stretch, or rotate any object with the mouse. After you've drawn an object, MacModel lets you calculate or change physical properties such as size, weight, density, and reflectance. Drawings can be printed with an Imagewriter or LaserWriter.

MacModel runs on any Mac, but synoptics recommends the 512K-byte version. The software costs $40. Contact synoptics, Suite 213, 1075 Bellevue Way NE, Bellevue, WA 98004, (206) 747-7633.
Inquiry **578.**

SOFTWARE • IBM PC

PC-to-PL/M Connector

CompuFirm has released an interface library of more than 150 functions and utilities designed to provide a connection between an IBM PC and Intel's PL/M compiler. This debugged set of assembly-language functions enables you to write various applications in the PL/M language using the Intel compiler.

PL/M Connection provides access to all of a PC's DOS and BIOS functions and high-speed graphics functions that interface directly with the color-graphics and monochrome display adapters. The package offers development support for software control of such peripherals as floppy and hard disks, communications devices, printers, video displays, and keyboards. The compiler generates in-line code automatically for the 8087 floating-point coprocessor.

The program consists of four main libraries plus utilities written in PL/M and assembly. For programmers unfamiliar with using PL/M to make a DOS program, CompuFirm has provided step-by-step sample programs explaining how to create such a program from the source code.

PL/M Connection comes on a double-sided PC-DOS disk with source code in PL/M and assembly, demo programs, and a 200-page manual with examples of each function. The package has a license fee of $295 per user. Quantity discounts and site licenses are available. Contact CompuFirm Corp., Suite 204, 7677 Ronson Rd., San Diego, CA 92111, (619) 571-0228.
Inquiry **579.**

On-line Correction Aid

The Resident Speller from S & K Technology is a memory-resident spelling-correction system for the IBM PC and compatibles. The program checks spelling as you type. It operates with many popular word processors, including WordStar, Microsoft Word, MultiMate, pfs:Write, WordPerfect, Volkswriter, and PeachText 5000. The Resident Speller can also be used as a stand-alone spelling checker for standard ASCII text files.

As a resident utility, the program occupies 25K bytes of memory; its 49,000-word dictionary takes another 64K bytes. You can turn checking on and off from within your word-processing environment. Configurable features include the interpretation of individual characters, the marking symbol and method, and default filenames. The main dictionary and alternate dictionaries can be expanded.

The Resident Speller costs $99. Contact S & K Technology Inc., 4610 Spotted Oak Woods, San Antonio, TX 78249, (512) 492-3384.
Inquiry **580.**

Lessons in Speedy Reading

Achievement House claims its FASTread program can help increase your reading rate with its 80 lessons of self-instruction, practice, and testing. The program also teaches the mental and physical aspects of fast reading to help you increase comprehension and retention along with speed.

The lessons use "real world" material with a difficulty level equivalent to what's found in industry and education. You set your own pace and goals, and the software tracks your progress. The program keeps tabs of where you finish in a lesson so you can resume with subsequent material quickly.

FASTread costs $59.95 and comes with a 30-day guarantee. It runs on an IBM PC, XT, or AT with at least 128K bytes, one disk drive, an 80 by 25 display, and DOS 2.0 or later. Contact Achievement House, 103 Great Plain Rd., Danbury, CT 06811, (800) 551-1133; in Connecticut, (203) 748-0277.
Inquiry **581.**

PLZ Compiler

KCSystems has developed a resident PLZ compiler that follows Lattice C calling conventions and can be used with any Lattice C-compatible library. The company said its compiler implements the complete Zilog PLZ language, including the extensions of the Z8000 PLZ (32-bit data types, structure operations, etc.). A version for the 68000 running under CP/M-68K is also available.

KCSystems said the compiler is best suited for ROM-based 8088/8086 or 68000 systems, systems-level programs, and any application where C or Modula-2 would otherwise be used.

The package costs $75 and consists of the compiler, user's manual, *Report on the Programming Language PLZ-SYS* (T. Snoock et al., Springer-Verlag, 1978), and a year of free updates. Or you can buy the manual and text for $20; the money is credited toward purchase of the compiler. A money-back guarantee runs for 30 days. Contact KCSystems, 20 Lamington Dr., Succasunna, NJ 07876, (201) 927-9104.
Inquiry **582.**

(continued)

SOFTWARE • OTHER COMPUTERS

Two for the Amiga

MaxiCorp has released a set of business-oriented modules and a serial communications program for the Commodore Amiga.

Maximillian contains four modules: MaxiCalc, a spreadsheet that can handle 256 rows by 256 columns; MaxiWord, a word processor; MaxiGraph, for drawing bar, line, and pie charts; and MaxiTerm, a communications program that can operate with data speeds up to 9600 bps. With a 256K-byte Amiga, you can use any one of the applications; with a 512K-byte machine, you can use all four together.

MaxiComm, another communications program, is capable of terminal emulation and file transfers between the Amiga and on-line services and data transfers between Amigas. Both XON/XOFF and XMODEM protocols are available.

Maximillian lists for $195. MaxiComm is $49.95. Contact MaxiCorp, 2817 Sloat Rd., Pebble Beach, CA 93953, (408) 625-4104.
Inquiry 583.

RAM Disk, RAM Upgrade for 520ST

Lamar Micro has developed a RAM-disk program for the Atari 520ST. Called RAM Overdrive, the program lets a 520ST with 1 megabyte of RAM address the upper 512K bytes of random-access memory as a RAM disk.

One way to fatten your Atari so it can use the RAM disk is with Lamar's 1-megabyte RAM upgrade. When used with a word-processing program such as ST Write, this RAM expansion lets approximately 688K bytes (or 344 typewritten pages) reside in memory at all times. The operating system automatically detects this increase and makes the 688K bytes available to the application.

RAM Overdrive costs $34.95. The RAM upgrade is $300. You have to send your keyboard to the company for installation of the RAM. Contact Lamar Micro, 2107 Artesia Blvd., Redondo Beach, CA 90278, (213) 374-1673.
Inquiry 584.

Pascal for Ataris

Draper Pascal lets you create, compile, and execute Pascal programs on the Atari 400, 800, XL, or XE computers. It incorporates features from UCSD and ISO standards and has extensions, such as sound and graphics, that take advantage of Atari hardware.

Machine-language subroutines can be loaded and called, and program chaining is supported. Draper puts no limit on the size of source-code programs. A one-pass compiler generates pseudocode directly; maximum size of program pseudocode is 30K bytes. Execution debugging tools include instruction trace and stack display. No linking is required.

Draper Pascal needs only one disk drive and 48K bytes of RAM. It costs $44.95 (plus $2 shipping) and comes with a manual and sample programs. Contact Draper Software, 307 Forest Grove, Richardson, TX 75080, (214) 699-9743.
Inquiry 585.

CP/M for Z8000

Digital Research and Zilog have jointly developed CP/M-8000 for the Z8000 16-bit microprocessor. CP/M-8000, which is being marketed by Toshiba and Zilog, features an enlarged directly accessible memory space beyond 64K bytes. The developers say the new CP/M has an improved file manager and command repertoire as well as increased capability for library maintenance.

CP/M-8000 comes with a C compiler, assembler, linker, debugger, and utilities. Personal BASIC, Compiler BASIC, FORTRAN, and Pascal/MT+ are slated as options. Toshiba's offerings for the operating system are a PL/M compiler, a macro assembler, a PROM writer, a download utility, and a screen editor.

The new CP/M can operate with a Z8001, Z8002, Z8003, or Z8004; a minimum of 176K bytes (256K is recommended); and up to 16 disk drives. It comes on single-sided single-density 8-inch floppy disks or on double-sided double-density 5¼-inch disks. Prices start at $340.

Contact Toshiba Corp., 1-1-1, Shibaura, Minato-ku, Tokyo 105, Japan; telephone: (03) 457-2104; Telex: J22587.
Inquiry 586.

Atari Tools

Volume One of the Atari ST Toolbox contains five utility programs on a single disk. The programs are Disk File/Sector Editor, Memory Editor, Fast Format & Copy, Deleted File Recovery, and Directory Print. Volume One costs $39.95.

Contact Mirage Concepts Inc., Suite 108, 4055 West Shaw Ave., Fresno, CA 93711, (209) 227-8369.
Inquiry 587.

Software-Development System

Described as a fourth-generation language, Sculptor is designed to reduce programming time by using menus written in plain English and screens created with any text editor. Microprocessor Developments Ltd. says Sculptor can cut programming time by as much as 80 percent.

The system uses a B-tree access method. It's transportable to a variety of computers using MS-DOS or PC-DOS. Multiuser applications can be developed for systems running under UNIX, UniFLEX, and OS-9.

Contact Microprocessor Developments Ltd., 1/3 Canfield Place, London NW6 3BT, England; telephone: 01-328-2277. The U.S. representative is Gander & Flynn Ltd., 225 Dyer Rd., West Palm Beach, FL 33405, (305) 832-0131.
Inquiry 588.

WHERE DO NEW PRODUCT ITEMS COME FROM?
The new products listed in this section of BYTE *are chosen from the thousands of press releases, letters, and telephone calls we receive each month from manufacturers, distributors, designers, and readers. The basic criteria for selection for publication are: (a) does a product match our readers' interests? and (b) is it new or is it simply a reintroduction of an old item? Because of the volume of submissions we must sort through every month, the items we publish are based on vendors' statements and are not individually verified. If you want your product to be considered for publication (at no charge), send full information about it, including its price and an address and telephone number where a reader can get further information, to* New Products Editor, BYTE, 70 Main St., *Peterborough,* NH 03458.

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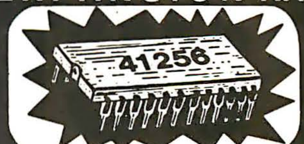
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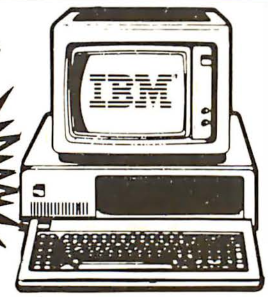
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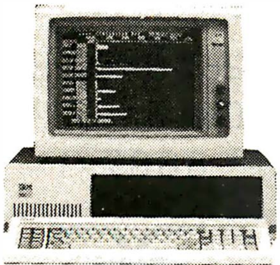
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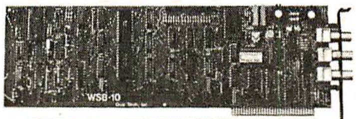
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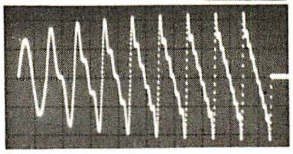
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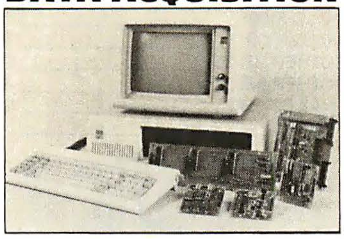
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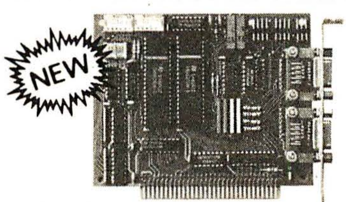
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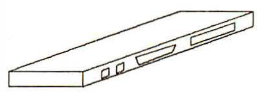
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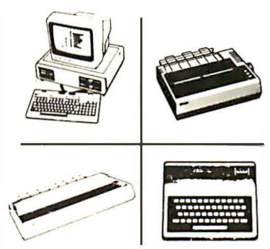
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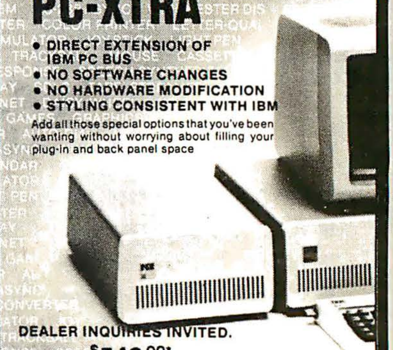
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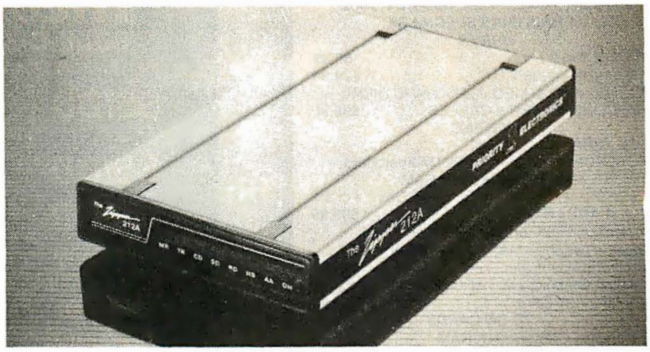


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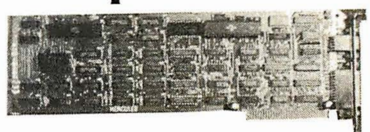


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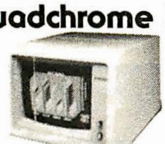
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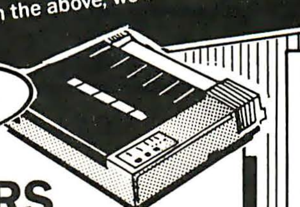
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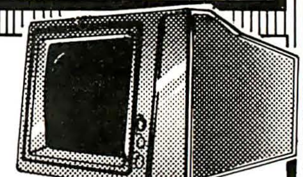
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A NEW COMPANY WAS NEEDED AND STARTED

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HOW SUPER DISK DISKETTES ARE MANUFACTURED

The *Super Disk* crew then assembled the newest, totally quality monitored, automated production line in the industry. Since the manufacturing equipment at *Super Disk* is new, it's easy for *Super Disk* to consistently make better diskettes. You can always be assured of ultra-tight tolerances and superb dependability when you use *Super Disk* diskettes. If all this manufacturing mumbo-jumbo doesn't impress you, we're sure that at least one of these other benefits from using *Super Disk* diskettes will:

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2. **COMPLETE LINE OF PRODUCTS** - For a diskette to be useful to you and your computer, it must be compatable physically. *Super Disk* has an entire line of 5¼-inch diskettes for your computer.
3. **SPECIALLY LUBRICATED DISK** - *Super Disk* uses a special oxide lubricant which is added to the base media in the production of their diskettes. This gives you a better disk drive head to media contact and longer head and disk life.
4. **HIGH TEMPERATURE/LOW-MARRING JACKET** - A unique high temperature and low-marring vinyl jacket allows use of their product where other diskettes won't work. This special jacket is more rigid than other diskettes and helps eliminate dust on the jacket.
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7. **CUSTOMER ORIENTED PACKAGING** - All *Super Disk* disks are packaged 10 disks to a carton and 10 cartons to a case. The economy bulk pack is packaged 100 disks to a case without envelopes or labels.
8. **LIFETIME WARRANTY** - If all else fails, remember, all disks made by *Super Disk* Inc., have a lifetime warranty. If any *Super Disk* diskette fails to meet factory specifications, *Super Disk* Inc. will replace them under the terms of the *Super Disk* warranty.
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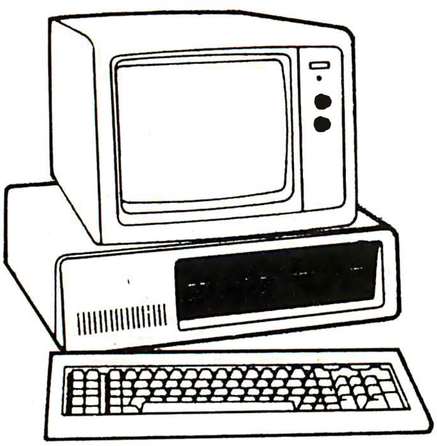
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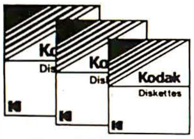
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Shipping: 5¼" & 3.5" DISKETTES—Add $3.00 per each 100 or fewer diskettes. **Other Items:** Add shipping charges as shown in addition to other shipping charges. **Payment:** VISA and MASTERCARD accepted. **COD Orders:** Add additional $5.00Special Handling charge. **APO, FPO, AK, HI & PR Orders:** Include shipping charges as shown **and** additional 5% of total order amount to cover PAL and insurance. **Taxes:** Illinois residents only, add 7% sales tax.

Prices subject to change without notice.
This ad supercedes all other ads.
Not responsible for typographical errors.
MINIMUM TOTAL ORDER: $35.00

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629 Green Bay Road • Wilmette, Illinois 60091

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Brand new ribbons, manufactured to Original Equipment Manufacturer's specifications, in housings. (Not re-inked or spools only.)

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Epson MX-100 .... **$4.08** ea. + 25¢ Shpng.
Okidata Micro83 .. **$1.37** ea. + 25¢ Shpng.
Okidata Micro84 .. **$2.98** ea. + 25¢ Shpng.

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ATHANA DISKETTES The great unknown!

60¢ ea. ← 5¼" SSDD Qty. 50 — 5¼" DSDD → **74¢** ea. Qty. 50

You've used these diskettes hundreds of times...as copy-protected originals on some of the most popular software packages. They're packed in poly-bags of 25 with Tyvek sleeves, reinforced hubs, user identification labels and write-protect tabs.

LIFETIME WARRANTY!

SOFT SECTOR ONLY! Sold in multiples of 50 only.

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AMARAY MEDIA-MATE 50: A REVOLUTION IN DISKETTE STORAGE



Every once in a while, someone takes the simple and makes it elegant! This unit holds 50 5¼" diskettes, has grooves for easy stacking, inside nipples to keep diskettes from slipping and several other features. We like it! **$9.69** ea. + $2.00 Shpng.

DISKETTE 70 STORAGE: STILL A GREAT BUY. Dust-free storage for 70 5¼" diskettes. Six dividers included. An excellent value. **$9.95** + $3.00 Shpng.



DISK CADDIES The original flip-up holder for 10 5¼" diskettes. Beige or grey only. **$1.65** ea. + 20¢ Shpng.

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DISK WORLD! The value leader in Computer supplies And accessories.

Inquiry 109

What the world really needs is a 69 cent Double Sided, Double Density Diskette with a LIFETIME WARRANTY!

And DISK WORLD! has it.

Introducing Super Star Diskettes: the high quality diskette with the lowest price and the best LIFETIME WARRANTY!

In the course of selling more than a million diskettes every month, we've learned something: higher prices don't necessarily mean higher quality.

In fact, we've found that a good diskette manufacturer simply manufactures a good diskette...no matter what they charge for it. (By way of example, consider that none of the brands that we carry has a return rate of greater than 1/1,000th of 1 percent!)

In other words, when people buy a more expensive diskette, they aren't necessarily buying higher quality.

The extra money might be going toward flashier advertising, snazzier packaging or simply higher profits.

But the extra money in a higher price isn't buying better quality.

All of the good manufacturers put out a good diskette. Period.

How to cut diskette prices ...without cutting quality.

Now this discovery posed a dilemma: how to cut the price of diskettes without lowering the quality.

There are about 85 companies claiming to be "diskette" manufacturers.

Trouble is, most of them aren't manufacturers.

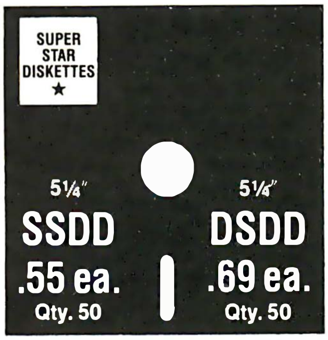
Rather they are fabricators or marketers, taking other company's components, possibly doing one or more steps of the processing themselves and pasting their labels on the finished product.

The new IBM diskettes, for example, are one of these. So are IBM 5¼" diskettes. Same for DYSAN, Polaroid and many, many other familiar diskette brand names. Each of these diskettes is manufactured in whole or in part by another company!

So, we decided to act just like the big guys. That's how we would cut diskette prices...without lowering the quality.

We would go out and find smaller companies to manufacture a diskette to our specifications...specifications which are higher than most...and simply create our own "name brand" diskette.

Name brand diskettes that offered high quality at low prices.



Super Star diskettes are sold in multiples of 50 only. Diskettes are shipped with white Tyvec sleeves, reinforced hubs, user ID labels and write-protect tabs.

Boy, did we get lucky. Our Super Star Diskettes are the same ones you've been using for years...without knowing it.

In our search for the low priced, high quality diskette of our dreams, we found something even more interesting.

We found that there are several manufacturers who don't give a hoot about the consumer market for their diskettes. They don't spend millions of dollars in advertising trying to get you, the computer user, to use their diskettes.

Instead, they concentrate their efforts on turning out the highest quality diskettes they can...because they sell them to the software publishers, computer manufacturers and other folks who (in turn) put their name on them...and sell them for much higher prices to you!

After all, when a software publisher or computer manufacturer or diskette marketer puts their name on a diskette, they want it to work time after time, everytime. (Especially software publishers who have the nasty habit of copy-protecting their originals!)

Super Star Diskettes. You already know how good they are. Now you can buy them...cheap.

Well, that's the story.

Super Star diskettes don't roll off the boat from Pago-Pago or emerge from a basement plant just east of Nowhere.

Super Star diskettes have been around for years...and you've used them for years as copy-protected software originals, unprotected originals. Sometimes, depending on which computer you own, the system master may have been on a Super Star diskette. And maybe more than once, you've bought a box or two or more of Super Star diskettes without knowing it. They just had some "big" company's name on them.

Super Star Diskettes are good. So good that a lot of major software publishers, computer manufacturers and other diskette marketers buy them in the tens or hundreds of thousands.

We buy them in the millions.

And than we sell them to you.

Cheap.

When every little bit counts, it's Super Star Diskettes.

You've used them a hundred times...under different names.

Now, you can buy the real McCoy, the same diskette that major software publishers, computer manufacturers and diskette marketers buy...and call their own.

We simply charge less.

FRAUD ALERT!

Please be careful!

A lot of the "no-name" diskettes flooding the market at prices of less than $1.00 are what we in the industry call "floor sweepings."

In other words, they're garbage...stuff that six months ago, no self-respecting manufacturer would have sold.

But times got tough and some people's scruples got a little lost in desperation...and so a lot of computer users are getting some really bad disks...and that isn't bargain at all.

So, when the price seems too good to be true...like 39 cents, be careful...very careful!

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FOR FASTEST SERVICE, USE NO-COST MCI MAIL: Our address is DISKORDER. It's a FREE MCI MAIL letter. No charge to you. (Situation permitting, we'll ship these orders in 24 hours or less.)

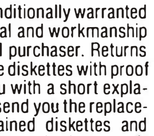
SHIPPING: 5¼" & 3½" DISKETTES—Add $3.00 per each 100 or fewer diskettes. **OTHER ITEMS:** Add shipping charges as shown in addition to other shipping charges. **PAYMENT:** VISA, MASTERCARD and Prepaid orders accepted. **COD ORDERS:** Add additional $5.00 special handling charge. **APO, FPO, AK, HI & PR ORDERS:** Include shipping charges as shown and additional 5% of total order amount to cover PAL and insurance. We ship only to United States addresses, except for those listed above. **TAXES:** Illinois residents, add 7% sales tax.

MINIMUM ORDER: $35.00.

Super Special!

Store 75 diskettes for only $5.95!

Yep, that's right: order 50 Super Star diskettes, add $5.95 and we'll include a Media Products DISK MINDER II...a well made unit that we're impressed with.



It holds 75 diskettes securely and looks nice too!

The Super Star LIFETIME WARRANTY!

Super Star Diskettes are unconditionally warranted against defects in original material and workmanship so long as owned by the original purchaser. Returns are simple: just send the defective diskettes with proof of purchase, postage-paid by you with a short explanation of the problem, and we'll send you the replacements. (Incidentally, coffee stained diskettes and diskettes with staples driven through them don't qualify as "defective".)

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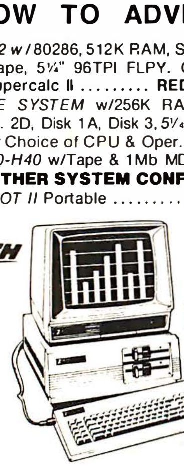
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VIASYN *CORE SYSTEM* w/256K RAM, I/F-4, Syst. Supp. 1, ENCL. 2D, Disk 1A, Disk 3, 5¼" FLPY, & 10Mb H.D. Add Your Choice of CPU & Oper. Sys.... **$3,949**
VIASYN *816/10-H40* w/Tape & 1Mb MDrv **$6,377**
CALL FOR OTHER SYSTEM CONFIGURATIONS
MORROW *PIVOT II* Portable .... **CALL**

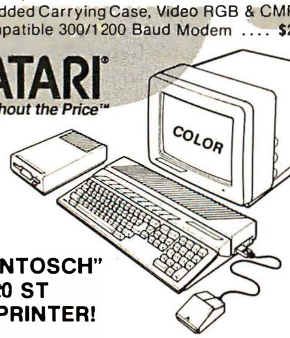
ZENITH data systems



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PC-INSIDER-72 72Mb Formatted **$2,385**
PC-OUTSIDER-72 W/T 72Mb & 60Mb Tape ... **$3,166**
PC-INSIDER-116 116Mb Formatted **$4,175**
PC-OUTSIDER-116 W/T 116Mb & 60Mb Tape . **$5,415**
AT-INSIDER-33 33Mb Formatted **$995**
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MPS *8465* Dual 5" & 8" Horizontal Slimline...... **$225**
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MPS *5505* 5¼" H.D. & ½ HT Flpy or Tape **$209**
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MICROWARE *DUAL HORIZ.* 5¼" ½ HT. Floppy .. **$79**
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STB *RIO PLUS II* 64K-512K, S.P, Clock **$216**
STB *RIO GRANDE PC-AT* 128K.-1.5Mb, 2S,P&G **$319**
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TECMAR *EXPANSION CHASSIS* With 8 Slots... **$675**
TECMAR *MAESTRO* Unpopulated for IBM-AT .. **$325**
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STB *SUPER RES 400* Color Hi-Res w/ 32K...... **$325**
TECMAR *GRAPHICS MASTER* 16 Color Hi-Res. **$439**
TECMAR *GRAPHICS TENDER* RGB/PRT Port .. **$195**
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VECTRIX *VXPCA* 4096 Colors .... Close-Out**$1,899**
VECTRIX *VX/PC* Video Cable **$79**

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AMDEK *300G* **$129**
PRINCETON GRAPHICS *SR-12* 690X480 RGB .. **$599**
TATUNG *CM-1322* 640X200 RGB Same as IBM . **$375**
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ZENITH *ZVM135* Hi-RES RGB w/ Green Switch . **$459**
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A Few Of This Month's SPECIALS Are: ....

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ACKERMAN *KLUGE CARD A&T* **$175**
ACKERMAN *PROMBLASTER II* Up to 27256K'S . **$306**
ACKERMAN *PROMBLASTER EXTENDER* **$79.95**
SPECTRONICS *PE24T/9 EPROM ERASER/TIMER* **146**
ADV. DIGITAL *SUPER 186/256K MASTER* **$1,495**
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CCS *2710* 4 Port Serial Board **$275**
CCS *2720* 4 Port Parallel Board **$215**
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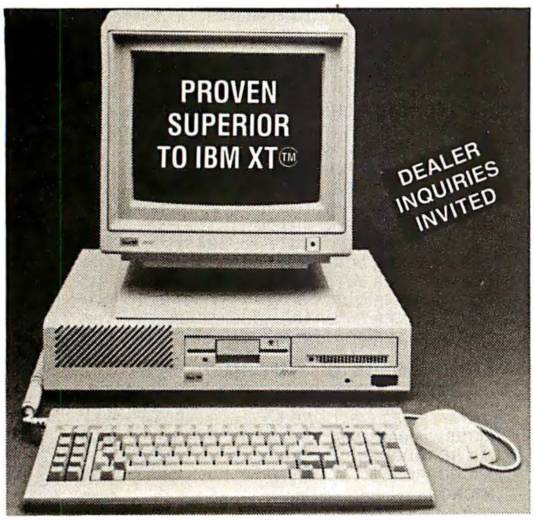
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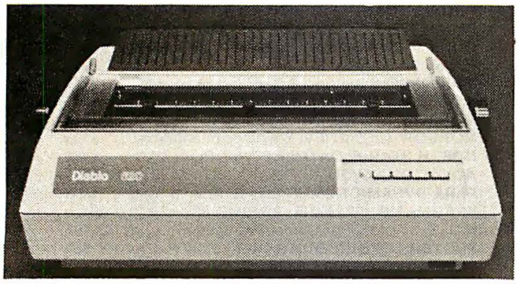
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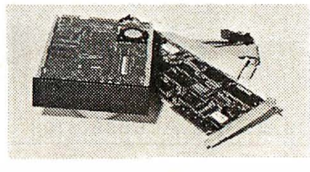


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Mini Size Green	.19	.16
Mini Size Yellow	.19	.16

SPECIAL VALUES!

MCM68705 EPROM	$9.95
6116/2016-150mS	10/19.95
DB-25P Male	10/17.50
DB-25S Female	10/19.95
2732A-2	10/29.95
2716DC-450mS	10/24.50
2764-450mS	10/29.95

CALL ACP FOR ALL YOUR VOLUME IC REQUIREMENTS

IC SOCKETS

SOLDERTAIL	1-99	100
8 Pin ST/LP	$ .13	$ .10
14 Pin ST/LP	.15	.11
16 Pin ST/LP	.17	.12
18 Pin ST/LP	.20	.17
20 Pin ST/LP	.28	.26
22 Pin ST/LP	.29	.27
24 Pin ST/LP	.29	.27
28 Pin ST/LP	.39	.32
38 Pin ST/LP	.45	.36
40 Pin ST/LP	.48	.42
64 Pin ST/LP	3.95	3.25
WIREWRAP (GOLD)	**1-99**	**100**
8 Pin WW/3L	$ .49	$ .40
14 Pin WW/3L	.62	.49
16 Pin WW/3L	.65	.55
18 Pin WW/3L	.88	.77
20Pin WW/3L	.99	.98
22 Pin WW/3L	1.19	1.13
24 Pin WW/3L	1.25	1.17
28 Pin WW/3L	1.49	1.39
40 Pin WW/3L	1.89	1.75

TEXTOOL/ZIF ZERO INSERTION
16 Pin $6.75 24 Pin $7.85 28 Pin $8.95
(We Stock All Types of Sockets)

EDGE CONNECTORS

	1-99	100
S-100ST	$3.95	$3.25
S-100 WW	4.75	4.10
44 Pin ST	2.75	2.60
44 Pin WW	4.75	4.25
72PinST	6.50	6.10
72PinWW	7.25	6.95

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	1-24	25
DB25S (Female	$3.10	$2.90
DB25P(Male)	2.40	2.29
Hood $1.25 Mtg H/W $ .99		
DE37S (Female)	$5.95	$5.75
DE37P (Male)	5.25	5.10
Hood $1.75 Mtg H/W $ .99		
DD50S (Female)	$8.95	$8.65
DD50P (Male)	6.00	5.75
Hood $3.25 Mtg H/W $ .99		

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IDC 36 Pin Female	9.49
Solder 36 Pin Male	7.49
Solder 36Pin Female	8.95

(CALL TOLL FREE FOR IDC's)

IDC CONNECTORS

IDC TYPE	ACP NO	NUMBER OF CONTACTS 10	20	26	34	40	50
Solder Header	IDHxxS	.79	1.20	1.65	2.10	2.40	3.00
Rt Angle Solder Header	IDHxxSR	.79	1.20	1.65	2.10	2.40	3.00
Ribbon Header Socket	IDSxx	.75	.95	1.35	1.50	1.85	2.10
Ribbon Header	IDMxx	—	5.25	5.95	6.75	7.25	8.25
Ribbon Edgecard	IDExx	1.70	2.15	2.50	2.60	3.70	3.95
Wirewrap Header	IDHxxW	1.80	2.90	3.75	4.25	4.95	6.50
Rt Angle W/W Header	IDHxxWR	1.99	3.10	4.10	4.20	4.60	7.15

NOTE: To order insert number of contacts in place of xx in ACP part number.
ORDER QUANTITY OF 50pcs (mixed) AND TAKE AN ADDITTIONAL 10% OFF.

EPSON PRINTERS

FX-85 (160cps)	$369.00
FX-185 (160cps)	515.00
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FX-80 +	339.00

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Toshiba 1340	$399.00
Toshiba 341	949.00
Toshiba 351	1099.00
Star SG-10	239.00
Brother 1509	399.00

6800

66000	$19.95	6810	$ 2.85	6850	$ 3.25
68000L10	39.95	6820	3.75	6852	5.65
6800	2.90	6821	2.90	6860	7.90
6802	7.75	6828	14.50	6875	6.75
6803	18.95	6840	12.75	6880	2.20
6809E	9.50	6845	11.95	68047	22.95

6500

6502	$4.50	6504	$8.75	6522	$5.25
6502A	8.90	6507	9.75	6532	9.50
6502B	9.50	6520	4.25	6551	11.50

8000

8035	$ 5.75	8214	$ 3.75	8259	$ 6.75
8039	5.75	8216	1.95	8271	69.95
8080A	2.95	8224	2.20	8275	26.95
8085A	4.90	8226	1.95	8279	8.75
80C85A	9.95	8228	3.40	8282	6.25
8086	24.50	8237	13.75	8283	6.25
8087-2	129.95	8237-5	15.95	8284	5.50
8088	17.50	8238	4.25	8286	6.45
8089	88.95	8243	3.95	8287	6.45
8155	8.75	8250	10.50	8288	11.95
8156	8.75	8251	4.25	8289	44.95
8185	26.95	8251A	5.95	8292	12.95
8202	23.95	8253	6.75	8741	27.95
8203	37.95	8255	4.25	8748	24.50
8205	3.25	8255A	5.95	8749	24.50
8212	1.95	8257	5.75	8755A	34.95

Z-80

	2.5MHz	"A" 4.0MHz	"B" 6.0MHz
Z80-CPU	2.25	2.75	6.95
Z80-CTC	2.50	3.75	9.25
Z80.DART	7.50	8.50	17.95
Z80-DMA	8.00	6.95	17.95
Z80-PIO	2.95	3.50	9.50
Z80-SIO/0	8.50	9.50	22.95
Z80-SIO/1	8.50	9.50	—
Z80-SIO/2	8.50	9.50	22.95
Z80-SIO/9	8.50	9.50	—

Z8030	$34.95	Z8001	$34.95	Z6132	$32.95
Z8530	34.95	Z8002	34.95	Z8671	37.95

DISK CONTROLLERS

uPD765	$9.95	1797	$21.95	6843	$28.95
1771	15.95	2791	32.95	8272	19.95
1791	22.75	2793	32.95	1691	6.95
1793	21.50	2795	32.95	2143	6.95
1795	21.50	2797	27.95	9216	12.95

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6845	$11.95	8275	$28.50	TMS9918	$39.50
68B45	17.85	7220	34.95	8350	39.95
6847	11.50	5027	17.95	6545	14.95
46505	14.75	5037	21.95	8002	19.95
68047	19.50	NEC7220Graphics			34.95

UARTS/USARTS

1602B	$3.95	2350	$ 8.95	IM6403	$ 8.75
1013A	3.95	8250	10.50	TMS5501	14.95
1015A	6.75	IM6402	7.75	2651	8.95

EPROMS

1702 (1mS)	$ 3.90	2732A-4 (450nS)	$ 4.50
2708 (450nS)	3.65	2732A (250nS)	6.95
2758 (5V)	5.50	2732A-2 (200nS)	8.95
2716 (450nS)	1.95	2764 (450nS)	1.95
2716 (350nS)	3.95	2764 (250nS)	2.95
2516 (5V)	2.95	2764 (200nS)	4.95
TMS2716	7.50	TMS2564 (450nS)	9.95
TMS2532	5.60	MCM68764 (450nS)	19.95
2732 (450nS)	1.95	MCM68766(350nS)	21.95
2732 (250nS)	2.95	27128-3 (300nS)	9.50
2732 (200nS)	4.95	27128 (250nS)	15.95
CMOS EPROMS		27C32	$5.95
27C16	$4.95	27C64	6.95

STATIC RAMS

2101 (450nS)	$1.89	MK4118	$4.95
21L02 (450nS)	.99	TMM2016-2 (200nS)	3.10
2102-1 (450nS)	.79	TMM2016-15 (150n)	3.95
21L02-2 (250nS)	1.39	TMM2016-1 (100nS)	3.00
2111 (450nS)	2.75	HM6116P-4 (200nS)	4.75
2112 (450nS)	2.75	HM6116P-3 (150nS)	3.25
2114 (450nS)	1.45 8/9.50	HM6116P-2 (120nS)	5.75
2114L-4 (450n)	1.69 8/12.50	HM6116LP-4 (LP)	3.60
2114L-3 (300n)	1.79 8/13.30	HM6116LP-3 (LP)	3.95
2114L-2 (200n)	1.69 8/13.90	HM6116LP-2 (LP)	3.95
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4044-4(450nS)	3.25	HM6264P-15 (150)	14.95
4044-3 (300nS)	3.75	HM6264LP-15 (LP)	16.95
4044-2 (200nS)	4.35	74S189 (35nS)	1.65
UPD410(100nS)	3.75	93415 (50nS)	3.95
5101 (CMOS)	3.50	93425 (50nS)	3.95

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4116N-2(150nS)	.85	41256-150 (150n)	2.75
4116N-3 (200nS)	.65	41256-200 (200n)	2.75
4116N-4 (250nS)	.49	TMS4050(300nS)	1.85
4164N-150 (150n)	9/7.95	TMS4060 (300nS)	1.85
4164N-200 (200n)	9/7.50	MM5260 (300nS)	1.85
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4001	.22	4029	.75	4060	.85	4506	1.10
4002	.22	4030	.39	4066	.39	4507	1.10
4006	.79	4031	3.25	4069	.28	4508	1.90
4007	.22	4032	2.15	4070	.35	4510	.79
4008	.95	4034	1.91	4071	.28	4511	.79
4009	.39	4035	.79	4072	.28	4512	.79
4010	.39	4037	1.95	4073	.28	4514	1.18
4011	.24	4040	.75	4075	.28	4515	1.79
4012	.24	4041	.75	4076	.75	4518	1.19
4013	.35	4042	.65	4077	.35	4518	.85
4014	.75	4043	.85	4078	.35	4520	.75
4015	.39	4044	.69	4081	.29	4555	.95
4016	.35	4046	.60	4082	.29	4556	.95
4017	.65	4047	.89	4085	.95	4566	1.35
4018	.79	4048	.99	4086	.95	80C95	1.50
4019	.39	4049	.35	4093	.45	80C97	.49
4020	.69	4050	.34	4094	2.95	MC14408	12.95
4021	.69	4051	.75	4098	1.90	MC14409	12.95
4022	.69	4052	.75	4099	1.85	MC14410	9.95
4023	.25	4053	.78	4501	.69	MC14411	11.95
4024	.59	4055	3.95	4502	.95	MC14412	12.95
4025	.25	4056	2.95	4503	.49	MC14419	4.95
4027	.45						

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74C02	.29	74C85	1.89	74C175	1.15	74C374	2.35
74C04	.29	74C90	1.15	74C240	1.89	74C901	.59
74C08	.35	74C93	1.15	74C244	1.69	74C922	4.45
74C10	.35						

MORE 74C IN STOCK — ALSO IN CATALOG

LINEAR

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LM300H	.99	NE592	2.70	LM3914	$2.95
LM301N	.35	LM709N	.55	LM3915	2.95
LM304H	1.89	LM709H	1.90	LM3916	2.95
LM305H	.95	LM710	.68	MC4024	3.75
LM306H	4.75	LM711	.75	MC4044	4.35
LM307N	.40	LM715	3.95	RC4131	3.75
LM308CN	.65	LM723N	.55	RC4136	1.19
LM310CN	1.65	LM723H	.75	RC4151	3.75
LM311CN	.62	LM733	.98	CA3023	2.75
LM312H	1.75	LM739	1.85	CA3039	1.25
LM318CN	1.45	LM741CN	.33	CA3046	1.25
LM318H	1.55	LM741H	.40	CA3059	2.85
LM319N	1.19	LM741N	.29	CA3060	2.85
LM320 (see VRs)		LM747	.65	CA3065	1.69
LM324N	.55	LM748	.55	CA3080	1.10
LM339N	.95	LM1014	1.15	CA3081	1.60
LM340(see VRs)		LM1303	1.90	CA3082	1.60
LM348N	.95	LM1310	1.45	CA3083	1.55
LM358CN	.65	MC1330	1.65	CA3086	.80
LM359	1.75	MC1349	1.85	CA3089	2.95
LM360N	2.95	MC1350	1.15	CA3098	3.45
LM370N	4.95	MC1358	1.65	CA3130	1.29
LM373N	3.95	MC1372	6.75	CA3140	1.15
LM376N	3.75	LM1414	1.55	CA3146	1.79
LM377N	1.90	LM1558H	2.99	CA3160	1.49
LM380CN	.85	LM1800	2.35	LM13080	1.25
LM380N	1.05	LM1812	8.10	LM13600	1.45
LM381N	1.59	LM1830	3.40	LM13700	1.45
LM382N	1.35	LM1871	5.45	LF347	2.19
LM383N	1.95	LM1872	5.45	LF351	.60
LM384N	1.75	LM1877	3.20	LF353	.99
LM386N	.89	LM1889	1.90	LF355	1.10
LM387N	1.29	LM1896	1.70	LF356	1.10
LM389N	1.15	ULN2001	1.95	LF357	1.39
LM392N	.69	ULN2003	1.49	TL071CP	.79
LM723N	.48	XR2206	3.75	TL072CP	1.35
LM723H	.55	XR2207	2.90	TL074CN	1.90
NE531	2.85	XR2208	2.40	TL081CP	.59
NE555	.35	XR2211	3.75	TL084CN	1.90
NE556	.65	LM2877P	2.00	TL494	4.10
NE558	1.49	LM2878P	2.25	TL496	1.65
NE561	23.50	LM2900	.83	TL497	3.20
NE564	2.85	LM2901	.99	MC3423	1.49
LM565	.95	LM2903	.69	MC3453	4.95
LM566	1.45	LM2907	2.45	MC3456	1.29
LM567	.85	LM2917	2.85	MC3459	3.75
NE570	3.85	LM3900	.55	MC3469	5.25
NE571	2.90	LM3905	1.15	MC3470	7.95

VOLTAGE REGULATORS

7805T Also 8, 12, 15, 24V	.69	7905K Also 12, 15, 24V	1.39
78L05, 12, 15V	.65	79L05, 12, 15V	.75
78M06C	.89	LM309K	1.25
78MG/79MG	1.49	LM317H/K	1.25/3.85
78H05KC	8.75	LM323K	4.85
7805K Also 12, 15, 24V	1.29	LM337K	3.75
7905T Also 8, 12, 15, 24V	.79	LM338K	6.75
		LM350T	4.55
		LM350K	4.75

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5369	3.50	11C90	13.25	Digitalker	34.95
58167	12.25	MC15906	2.95	LM13600N	1.95
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ADC0800	$14.95	ADC0817	$9.75	1408L6	$1.95
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DAC0806	1.90	DAC0806	2.85	DAC100	7.95
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Toshiba ND04E-G for "AT"	99.50
Toshiba ND08DE-G 1.2Mb for "AT"	149.50

ALL WITH MOUNTING KIT

7400

7400	$ .18	7446	$ .66	74123	$ .45	74176	$ .89
7401	.18	7447	.65	74125	.42	74177	.89
7402	.18	7448	.68	74126	.44	74179	1.34
7403	.18	7450	.19	74128	.49	74180	.75
7404	.18	7451	.19	74132	.45	74181	1.75
7405	.23	7453	.19	74136	.75	74182	1.15
7406	.49	7454	.19	74141	.85	74184	2.25
7407	.49	7459	.25	74142	2.95	74185	2.25
7408	.24	7460	.37	74143	3.70	74190	.87
7409	.19	7470	.29	74144	2.95	74191	.87
7410	.19	7472	.29	74145	.59	74192	.87
7411	.24	7473	.33	74147	1.49	74193	.87
7412	.38	7474	.34	74148	1.19	74194	.87
7413	.34	7475	.38	74150	1.09	74195	.87
7414	.49	7476	.34	74151	.55	74196	.75
7416	.49	7479	4.60	74152	.67	74197	.86
7417	.49	7480	.69	74153	.53	74198	1.15
7420	.19	7482	.95	74154	1.19	74199	1.15
7421	.35	7483	.45	74155	.69	74221	1.19
7422	.45	7485	.55	74156	.59	74251	.75
7423	.58	7486	.35	74157	.58	74273	1.65
7425	.29	7489	1.05	74158	1.65	74276	1.68
7426	.29	7490	.35	74159	1.58	74279	.75
7427	.25	7491	.65	74160	.79	74283	1.40
7428	.55	7492	.45	74161	.69	74284	2.90
7430	.18	7493	.35	74162	.69	74285	2.90
7432	.29	7494	.85	74163	.89	74290	1.49
7437	.25	7495	.50	74164	.89	74298	1.49
7438	.29	7496	.69	74165	.69	74365	.55
7439	.58	7497	2.70	74166	.85	74366	.55
7440	.19	74100	1.50	74167	2.75	74367	.55
7441	.79	74107	.24	74170	1.25	74368	.55
7442	.45	74109	.37	74172	4.75	74390	1.45
7443	1.15	74116	1.45	74173	.69	74393	1.33
7444	1.15	74121	.29	74174	.89	74490	2.25
7445	.68	74122	.44	74175	.69		

74LS00

74LS00	$ .15	74LS113	$ .38	74LS247	$ .74
74LS01	.15	74LS114	.39	74LS248	.96
74LS02	.15	74LS122	.45	74LS249	.98
74LS03	.15	74LS123	.95	74LS251	.59
74LS04	.24	74LS124	2.75	74LS253	.59
74LS05	.25	74LS125	.49	74LS257	.59
74LS08	.27	74LS126	.49	74LS258	.59
74LS09	.28	74LS132	.59	74LS259	2.95
74LS10	.25	74LS136	.39	74LS260	.59
74LS11	.33	74LS139	.59	74LS261	2.49
74LS12	.33	74LS135	.59	74LS266	.55
74LS13	.39	74LS145	1.19	74LS273	1.45
74LS14	.59	74LS148	1.38	74LS275	3.29
74LS15	.33	74LS151	.55	74LS279	.56
74LS20	.26	74LS153	.55	74LS283	.86
74LS21	.29	74LS154	1.49	74LS290	.88
74LS22	.29	74LS155	.69	74LS293	.78
74LS25	.25	74LS156	.69	74LS295	.98
74LS27	.28	74LS157	.69	74LS298	.88
74LS28	.29	74LS159	.69	74LS324	1.75
74LS30	.25	74LS160	.69	74LS347	1.86
74LS32	.33	74LS161	.69	74LS348	1.95
74LS33	.53	74LS162	.69	74LS352	1.25
74LS37	.35	74LS163	.69	74LS353	1.25
74LS38	.39	74LS164	.69	74LS363	1.29
74LS40	.25	74LS165	.90	74LS365	.48
74LS42	.44	74LS166	1.90	74LS366	.48
74LS47	.74	74LS169	1.15	74LS367	.45
74LS48	.74	74LS168	1.15	74LS368	.45
74LS51	.25	74LS170	1.40	74LS373	1.32
74LS54	.29	74LS173	.67	74LS374	1.33
74LS55	.29	74LS174	.87	74LS375	.69
74LS73	.39	74LS175	.87	74LS377	1.38
74LS74	.34	74LS181	1.95	74LS385	1.95
74LS75	.39	74LS190	.85	74LS386	.45
74LS76	.39	74LS191	.85	74LS390	1.15
74LS78	.39	74LS192	.78	74LS393	1.15
74LS83	.59	74LS193	.78	74LS395	1.15
74LS85	.69	74LS194	.69	74LS399	1.47
74LS86	.39	74LS195	.89	74LS424	2.95
74LS90	.54	74LS196	.79	74LS668	1.75
74LS92	.54	74LS197	.79	74LS670	2.29
74LS93	.54	74LS221	.89	81LS95	1.45
74LS95	.75	74LS240	.95	81LS96	1.45
74LS96	.89	74LS242	.95	81LS97	1.45
74LS107	.39	74LS243	.95	81LS98	1.45
74LS109	.39	74LS244	1.25	25LS2521	2.59
74LS112	.39	74LS245	1.45	29LS2569	3.60

74S00/PROMS*

74S00	$.25	74S74	$.55	74S158	$.99	74S260	$1.19
74S02	.29	74S85	1.89	74S160	2.49	74S280	1.95
74S03	.29	74S86	.55	74S161	1.89	74S287*	1.95
74S04	.45	74S112	.55	74S174	1.19	74S288*	1.95
74S05	.45	74S113	.55	74S175	1.19	74S373	2.09
74S08	.39	74S114	.55	74S188*	1.49	74S374	2.09
74S09	.39	74S124	2.69	74S194	1.49	74S387*	1.95
74S10	.35	74S132	1.39	74S195	1.49	74S471*	5.95
74S11	.39	74S133	.45	74S196	1.49	74S472*	4.95
74S15	.35	74S134	.50	74S240	1.99	74S473*	4.95
74S20	.39	74S135	.89	74S241	1.99	74S474*	4.95
74S22	.35	74S136	1.39	74S242	1.99	74S475*	4.95
74S30	.35	74S139	.89	74S243	1.99	74S570*	2.95
74S32	.45	74S135	.89	74S244	1.99	74S571*	2.95
74S38	.89	74S140	.55	74S251	1.19	74S572*	4.95
74S40	.39	74S151	.99	74S253	1.19	74S573*	4.95
74S51	.35	74S153	.99	74S257	1.19	74S940	2.49
74S64	.39	74S157	.99	74S258	1.19	74S941	2.49
74S65	.39						

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California Digital

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XEROX $299

~~$2995~~

SUNRISE COMPUTER





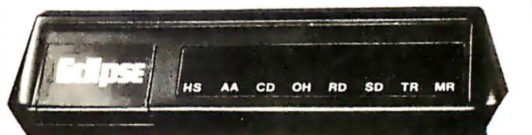


The Xerox Sunrise 1810 is by far the best value we have ever seen in a micro computer. This is a self contained battery and AC operated portable. The Sunrise was originally prices at $2995. Xerox has since elected to drop the computer from their product list. California Digital has purchased all the remaining inventory and is making the unit available at a fraction of its original cost.

This portable features a built in 80 column liquid crystal display, 64K of memory along with both RF monitor and television outputs. The internal 300/1200 baud modem includes an auto dial telephone assembly. The units has both centronics parallel and a serial port programmable to 19,200 baud. The self contained micro cassette is capable of capturing data from the keyboard as well as doubling as an recorder for dictating messages.

An optional dual floppy disk drive module, pictured above, is available for only $219. Also available, for $59 is an 80 column printer that mounts in the drive module. The Sunrise features a CP/M operating system which allows the operator to use any CP/M program in Xerox 5¼" disk format and over 5000 CP/M programs available in public domain.

We have available a 15 minute tape on the Sunrise Computer. The tape is in VHS format and was produced by Xerox to promote the computer. California Digital is offerthe promotional tape at $15. This will be applied towards purchase price of the Sunrise 1810.



Eclipse $179

DATA PRODUCTS

1200 Baud • Hayes Compatible

The Eclipse 1200 is the best value we have ever offered in a fully Hayes Compatible modem. The unit incorporates status lamps, speaker, auto dial and many more features into this compact package.

California Digital is so comfident of your complete satisfaction that we will allow the return of the Eclipse 1200 and apply the full credit towards the purchase price of any other modem.

IBM SUPPORT PRODUCTS



MEMORY & SPECIALTY BOARDS

Twix-Winchester, floppy and streamer tape	299
AST Six Pack64K, serial, par'l, clock/cal.	229
AST Six Pack as above but384k/Byte of mem.	239
AST Advantage 128K	419
ASTI/O plus clock/cal.,serial & game port	129
Quadram Quadboard II, 64K memory	279
Quadram QuadLink/Apple files	379
Persyst Time Spectrum card, 64K	239
DigiGraphics Multifuncition	219
Titan Tech. PC/Accellertor	499
Hexace RAM card 576K/byte	199
Hexace multifunction	119

GRAPHIC CARDS

Hercules Color Card	179
Hercules Graphic Card	319
Persyst BoB Board super hi-res color.	329
Hexace half slot video card	119
Peacock Color Card, composit/RGB, printer	139
California Comp. SuperVision graphics	379

INTERNAL MODEMS

Modtech UltraLink 1200, 202 half duplex	99
Anchor Auto. Signalman Mk6. 300 baud.	49
Promethus 1200B internal	279

HARDWARE

Tallgrass 60 meg. tape back-up	1459
Kraft IBM JoyStick	35
Microsoft Mouse, serial & paintbrush	145
Mouse Systems PC Mouse	149
8087 co-processor	119
Keytronics 5151 IBM keyboard	199
Belkin A/B switch. par'l or serial	59

SOFTWARE

MicroPro WordStar word processing	179
Ashton Tate Framework, spreadsheet+	395
Ashton Tate D/Base III, Data Base Manager	395
Lotus 1-2-3 spreadsheet & more	299
Symphony by Lotus development	419
Redwood Dev. Jr. CAD, plotter	59

1200 BAUD MODEMS



$159

The Universal Data 212A is manufactured for the mini-computer market. This modem is both 300 and 1200 baud auto answer. An industrial quality modem originally priced at $595. NOT Hayes compatible.

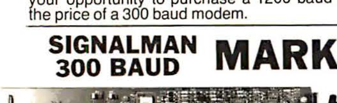
SMARTEAM 1200



$199

The Team 212A offers all the features of the Hayes Smart Modem 1200 for a fraction of the price. Now is your opportunity to purchase a 1200 baud modem at the price of a 300 baud modem.

SIGNALMAN 300 BAUD MARK VI



$49

The Anchor Automation Mark VI is a 300 baud direct connect modem that plugs into any slot of your IBM/PC. This modem supports auto answer and auto dial capabilities. Other features include telephone number storage, send / receive text files, single key-stroke dialing along with many other functions provided on disk. The Mark VI was originally priced at over $300.

UltraLink 1200



$99

The UltraLink is a 1200 baud HALF DUPLEX bell 202 compatible internal modem card for the IBM/PC. This unit operates full duplex at 300 baud.

The UltraLink adds a voice/data demension to your PC. Manufacturers original suggested price on this modem is $795. California Digitals price is only $99.

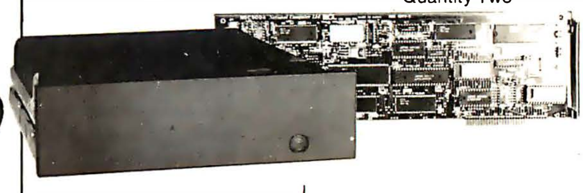
MODEMS

Eclipse 1200 100% Hayes, with status lamps.	ECP-1200	179.00
Universal Data 212LP, 1200 duplex, line powered.	UDS-212LP	139.00
Universal Data 212A, 300/1200 baud, industrial.	UDS-212A	159.00
Universal Data 103JLP, line powered, auto answer.	UDS-103LP	29.00
Hayes Smartmodem 2400 baud modem	HYS-2400	599.00
Fujitsu 2400/1200 baud auto everything.	FUJ-1935D	459.00
Team 1200 Hayes Compatible, 300/1200 baud.	TEM-SM1200	199.00
UltraLink 1200 data and voice on same line.	UTL-1200A	99.00
CTS 212AH 1200 baud, auto dial	CTS-212AH	219.00
Terminal software for CTS 212AH	CTS-212SFT	35.00
Prometheus 1200 super features	PRM-P1200	319.00
Prometheus 1200B internal PC	PRM-P1200B	279.00
Signalman Mark 12, 1200 baud, Hayes compatible.	SGL-MK12	239.00
Signalman Mark VI, 300 baud internal PC	SGL-MK6	49.00
Hayes Smart Modem 1200 baud, auto dial	HYS-212AD	389.00
Hayes 1200B for use with the IBM/PC, 1200 baud.	HYS-1200B	369.00
Hayes Smartmodem, 300 baud only, auto dial	HYS-103AD	199.00
Hayes Chronograph, time & date	HYS-CHR232	199.00
Penril 300/1200 industrial quality	PEN-12AD	395.00

Shugart $239

10 MEGABYTE WINCHESTER HARD DISK DRIVE

Quantity Two



Five Inch Winchester Disk Drives

	each	two+
SHUGART SA712 10 M. Ht.	259	239
SEAGATE ST506 6.7 Meg.	139	129
SEAGATE 225 20 Meg. ½ Ht.	389	359
SEAGATE 4026 26 M. 35mS.	859	829
SEAGATE 4051 51 M. 35mS.	1095	1059
FUJITSU 2242 55 M. 35mS.	1799	1729
FUJITSU 2243 86 M. 35mS.	2295	2219
RODIME RO-202E 27 Meg.	759	729
RODIME RO-203E 40 Meg.	995	959
RODIME RO-204E 53 Meg.	1259	1195
CONTROL DATA 94155-86 M.	1829	1779
MAXTOR XT1140 140 Meg.	3379	3295
HONEYWELL 85M. 27 mS.	1795	1695
TOSHIBA MK56 70 M. 30mS.	1789	1729
TANDON 502 10 Meg.	419	379

• Winchester Controllers for IBM/PC •

FALCON FT-HDC half card	189
XEBEC 1220 with floppy controller	269
NATIONAL COMPUTER 5004	159
OTC 5150BX	159
OMTI 5510 half card	189
ADAPTEC 2010A software install	189
WESTERN DIGITAL WO/1002	189

• SCSI/SASI Winchester Controllers •

XEBEC 1410A 5¼" foot print	239
OMTI 20L	119

• Winchester Accessories •

Installation Kit with manual	10
Winchester enclosure and supply	139
Dual 20/34 cable set	25
Switching power supply	49

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California Digital

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LETTER QUALITY F-10 DAISY WHEEL PRINTER

$429 Quantity Two

Single piece price $499. But if you have already purchased an F-10 printer from California Digital, we will honor the $429 price on the second printer.



The TEC F-10 Daisy Wheel printer is the perfect answer to a reasonablly priced 40 character word processing printer. While this printer is " extremely" similar to C.Itoh's F-10/40 Starwriter printer. Legal counsel for the C.Itoh Company have advised us that we should refrain from referring to the TEC printer as a Starwriter.

This 40 character per second printer auto installs with Wordstar and Perfect Writer. Features extensive built-in word processing functions that allow easy adaptability and reduced software complexity. Industry standard Centronics interface provides instant compatibility with all computers equiped with a parallel printer port. The TEC F-10 accepts paper up to 15 inches in width.

These printers were originally priced to sell at over $1400. Through a special arrangment California Digital has purchase these units from a major computer manufacturer and is offering these printers at a fraction of their original cost.

Options available include sheetfeeder, tractor feed, buffered memory and an assortment of printer cables for a variety of computers.

5¼" DISK DRIVE SALE $89

Quantity Two

Your Choice any 48 or 96 TPI drive
SHUGART ● TEAC ● QUME
MITSUBISHI ● MATSUSHITA



	One	Two	Ten
TEAC FD55B half height	99	89	89
TEAC FD55F 96 TPI, half ht.	119	89	89
TEAC FD55FG for IBM AT	189	179	175
SHUGART SA455 Half Height	99	89	89
SHUGART SA465 ½ Ht. 96TPI	99	89	89
TANDON 100-2 full height	129	125	119
MITSUBISHI 4851 half height	99	89	89
MITSUBISHI 4853 96/TPI½ Ht.	99	89	89
MITSUBISHI 4854 8" elec.	295	285	275
QUME 142 half height	99	89	89
Switching power supply			49
Installation Kit with manual			10
Dual enclosure for 5¼" drives			59
34 pin edge connectors			5
Scotch head cleaning kit			19
Flip & File Storage tubs			15

DUAL SHUGART SUBSYSTEM $239



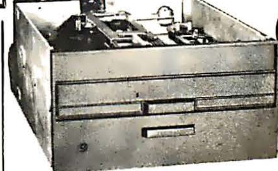
The dual Shugart subsystem features two SA465 (96 tpi) 5¼" double sided disk drives. Also supplied within the subsystem is 50 watt power supply and a shielded signal cable.

Uninterruptable Power Supply $239



If you loosing data due to "dirty" power and power failure, this uninterruptable supply is the ideal solution. The UPS supplies 250 watts of of clean power, free from RFI and EMI noise. The unit will support a IBM/XT system and color monitor upto 12 miniutes after power failure. Enough time to complete your program and come to a soft landing. The UPS can be sustained for addition hours by connecting to a 12 volt car battery. This is an inexpensive solution to a very costly problem.

QUME $149



Eight Inch Single Sided Drives

QUME 841 single side	159	149	call
SHUGART 801R	359	359	354
SIEMENS FDD 100-8	119	115	109

Eight Inch Double Sided Drives

QUME 842 "QUME TRACK 8"	189	179	call
SHUGART SA851R	495	485	475
OLIVETTI double sided	189	179	159
REMEX RFD-4000	179	169	159
MITSUBISHI M2896-63 ½ Ht.	459	449	409
Dual 8" enclosure with power and fan			259
Switching power supply			89
Installation kit with manual			10

PLOTTER $219



The Comrex Comscriber I is the ideal solution to make short work of translating financial and numeric data into a graphic presentation Many ready to run programs such as Lotus 1-2-3. Visi-on and Apple business graphics already support this plotter

The Comscriber I features programmable paper sizes up to 8½ by 120 inches. 6 inch per second plot speed and 0.004 step size Easy to implement Centronics interface allows the Comscriber I immediate use with the printer port of most personal computers

The Comscriber I is manufactured for Comrex by the Enter Computer Corporation. The plotter is marketed by Heath Kit and also sold under Enters own "Sweet P" Label. This is your opportunity to purchase a plotter which was originally priced at $795 for only $219

Also available is a support package which includes demonstration software, interface cable, a multicolor pen assortment and a variety of paper and transparency material

Quick-Link 300 $59



The Quick-Link 300 gives you an instant link to any dial up data base. Such as Dow Jones, Western Union or the Source. The Quick-Link has four user programmable log-on keys, allowing the operator, with only one key stroke, to dial the data base, log-in and give the password. All this information is permanently stored in non-volatile RAM.

Features include video output to television or monitor, auto dial, auto-log, full sized keyboard, 300 baud modem and 1200 baud auxillary printer port. All this is available for only $59.

NEC RGB COLOR MONITOR $219



The NEC JC-1401D is a 13" medium/high resolution RGB monitor suitable for use with the Sanyo MBC-550/555 or the IBM/PC The monitor features a resolution of 400 dots by 240 lines Colors available are Red, Green, Blue, Yellow, Cyan, Magenta, Black and While

The NEC monitor carries the Litton-Monroe label and was originally scheduled for use in their "Office of the Future" equipment A change in Monroe's marketing strategy has made these units excess inventory which were sold to California Digital We are offering these "new" RGB monitors at a fraction of their original cost. Sanyo compatible NEC-1401/S; IBM/P/C Computer compatible NEC-1401/PC

DRAGON $99



Compatible with most Radio Shack Color Computer software. The world famous Dragon computer is now available in the United States. Manufactured by the Tano Corp. under license of the British Broadcasting Company.

The Dragon comes complete with 64K Byte of memory, serial modem port along with a Centronics printer interface. This unique microcomputer features Motorola's advanced 6809E microprocessor and comes standard with Microsoft Color Basic, data base manager, and a complete word processing package. The computer outputs color composite video along with R.F. video that allows the unit to be used in conjunction with any color television.

This is the Ideal low cost computer to be used with any dial up information system such as the Source, EasyLink or any other time share service.

PRINTERS

MATRIX PRINTERS

Star Gemini-SG10 120 char/sec.	STR-SG10	239.00
Star Gemini-SG15, 100 char./sec. 15" paper.	STR-SG15	389.00
Star Gemini Delta 10, 160 Char/sec	STR-D10	359.00
Citizen MSP/10FT 160 char/sec.	CIT-MSP10	289.00
Toshiba P1351, 192 char/sec. letter quality	TOS-1351	1495.00
Okidata 182A serial & parallel 9½" paper	OKI-182A	257.00
Okidata 192A parallel interface, 160 char/sec.	OKI-192A	345.00
Okidata 84P parallel 15" paper	OKI-84P	789.00
Epson LX-80 10" 120 Char/sec.	EPS-LX80	239.00
Epson FX80FT, 10" 160 char./sec. with graphtrax	EPS-FX80	369.00
Epson RX100+ 15" withGraphtrax	EPS-RX100	389.00
Epson FX100FT 15" 160 char./sec with graphtrax	EPS-FX100	489.00
Epson LQ1500, 15" corespondence quality	EPS-LQ1500	89500
Epson JX80 Color printer	EPS-JX80	519.00
Prowriter 8510 parallel 9½" paper	PRO-8510P	329.00
Dataproducts B-600-3, band printer 600 LPM.	DPS-B600	6985.00
Printronix P300 high speed printer 300 lines per minute	PTX-P300	3995.00
Printronix P600 ultra high speed 600 lines per minute.	PTX-P600	5795.00

WORD PROCESSING PRINTERS

Starwriter F10 parallel, 40char/sec.	PRO-F10P	49900
NEC8810 55 char/second, serial interface	NEC-8810	1659.00
NEC8830 55 char/sec, par'l interface	NEC-8830	1659.00
NEC3550 popular printer designed for the IBM/PC	NEC-3550	1599.00
NEC2050 designed for IBM/PC 20 char/sec. par'l.	NEC-2050	68900
SilverReed EXP500, 14 char/sec. par'l interface	SRD-EXP500	319.00
Silver Reed EXP550 17 Char/sec par'l interface.	SRD-EXP550	429.00
Diablo 630 40 char/sec. serial	DBL-630	1569.00
Diablo 620, proportional spacing, horz.& vert. tab. 20 cps.	DBL-620	769.00
Juki 6100, 18 char./sec.	JUK-6100	399.00
Juki 6300, 40 char./sec.	JUK-6300	699.00
Comrex CR2, 5k buffer, proportional spacing, par'l.	CRX-CR2P	395.00

VISA

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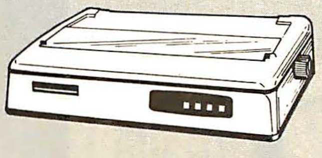
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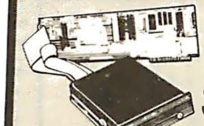
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For your IBM PC

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10 MEGABYTE Hard Disk System
FOR YOUR IBM PC **$389.95**



Complete with controller card, data cable, and mounting hardware, totally PC/XT compatible. For external model (cabinet & power supply)—add $199.

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20 MB Internal ½ High	$1550	$489.95
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20 MB Hi-Speed for AT	$1250	$699.95
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JADE 1200 External Baud Modem $179.95

	LIST	JADE
JADE 1200 Baud External	$349	179.95
JADE 2400 Baud External	$699	$499.95
JADE 1200B Internal	$349	$179.95
HAYES Smartmodem 2400	$899	$629.95
HAYES Smartmodem 1200	$699	$389.95
HAYES 1200B w/o Smartcom II	$539	$339.95
HAYES 1200B for IBM PC	$599	$359.95
HAYES Smartmodem 300	$289	$169.95
HAYES Micromodem IIe	$299	$169.95
HAYES Smartmodem IIc	$399	$169.95
Modem Cable	$35	$24.95
ProModem 300c for Apple IIc	$199	$149.95
ProModem 1200B for IBM PC	$399	$289.95
ProModem 1200 RS-232	$495	$299.95
ProModem 1200A for Apple	$449	$349.95
ProModem 1200 for Macintosh	$495	$349.95
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Options Processor	$99	$79.95
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Expand Your IBM PC, IBM PC-XT, IBM PC-AT

AST BOARDS ON SALE!

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AST Six Pak Plus 384K	$945	$299.95
AST Rampage 256K	$495	$379.95
AST Rampage 2 MB	$1995	$679.95
AST Advantage-AT 128K	$595	$399.95
AST Advantage-AT 3 MB	$4145	$999.95
IRMA 3270 Board	$1195	$988.95

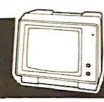
TALLTREE JRAM-2/JRAM-3

0K JRAM-2	$179.95
1 MB JRAM-2	$399.95
2 MB JRAM-2	$599.95
256K JRAM-3	$329.95
1 MB JRAM-3	$499.95
2 MB JRAM-3	$629.95

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For Your IBM PC		For IBM PC-AT	
64K	$349.95	128K	$529.95
256K	$399.95	512K	$629.95
512K	$449.95	1 MB	$729.95
1 MB	$549.95	2 MB	$929.95
2 MB	$749.95	4 MB	$1599.95

High Resolution Video Monitors



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Amdek 300G	$179	$139.95
Amdek 300A	$199	$149.95
Amdek 310A	$230	$179.95
PGS MAX-12 E 720 x 350	$269	$179.95
PGS HX-12 640 x 240	$699	$449.95
PGS HX-12E 690 x 350	$785	$549.95
Taxan 640 Ultra Hi-Res RGB	$799	$599.95
JADE Hi-Res TTL Monochrome 750 x 350 w/free tilt & swirl; green/amber	$229	$149.95

HIGH RESOLUTION 640 x 260, .38 Dot Pitch TAXAN 415 RGB COLOR MONITOR

Originally manufactured for Acorn Computer.

$289

LIST PRICE $699
IBM cable—$14.95

64K RAM Chip Upgrade Kits $9.99

High speed RAM upgrade kit with FREE parity (error detection) and one year warranty. We ship thousands of these kits to satisfied customers every week.

	LIST	JADE
128K RAM Chip Kit for AT	$395	$99.95
256K RAM Chip Kit	$99	$39.95

360K Disk Drive

IBM PC, XT or Compatibles.

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	LIST	JADE
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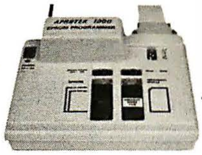
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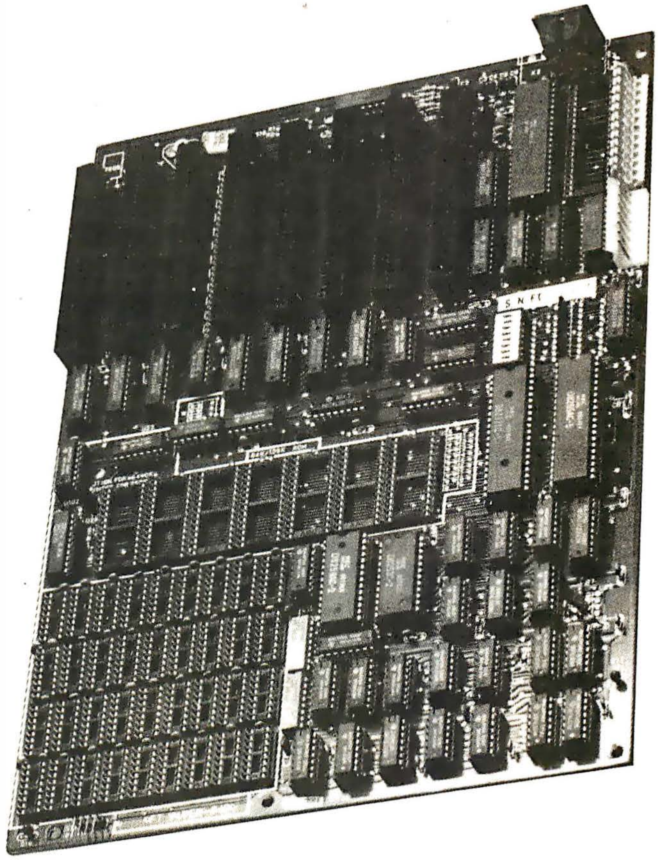
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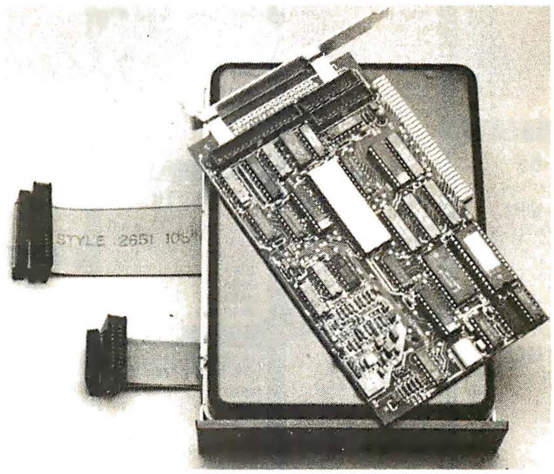
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74LS15	.26	74LS221	.59
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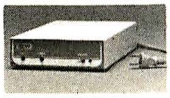
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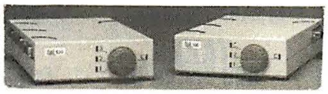
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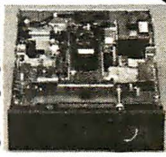
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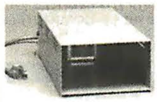
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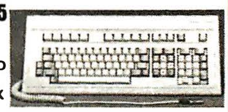
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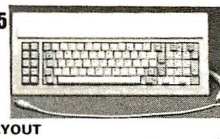


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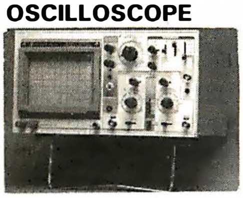
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TRADE: Two white-water rafting tickets in exchange for an IBM PC XT or compatible for our training adventure teaching people with severe cerebral palsy to use micros and obtain employment. Tax-deductible. Kathleen Martin, Computer Access Project, 1904 Franklin St., Oakland, CA 94612, (415) 832-7430.

NEEDED: Nonprofit school for emotionally disturbed children seeks tax-deductible donation of Apple computers, peripherals, literature, supplies, etc. Will provide receipts. Dean Esmay, SMA Independence High School, 22700 Richton Square Rd., Richton Park, IL 60471, (312) 481-6091.

WANTED: Volunteer programmer seeks contribution of IBM, Apple, or compatible, peripherals, and literature for Institution of Social Work and Community Development projects and development of public-domain educational programs for literacy training in underdeveloped areas. Jeffrey Y. Balanag, 3536 Road Ten, Altura St., Sta. Mesa, Metro-Manila 2806, Republic of the Philippines.

NEEDED: UNIX system, IBM or compatible micros, terminals, monitors, printers, and other equipment for training and user's group sponsored at Maine State Prison. Tax-deductible. George Fernald, Maine State Prison Jaycees, Box A, Thomaston, ME 04861, or call David Macmillan or Bruce Wentworth at (207) 354-2535, ext. 293.

WANTED: Tax-deductible IBM PC-compatibles, monitors, printers, and copying machines for U.S. professors helping revive scientific psychology in China through graduate program at Liaoning Teachers University. Macintosh with printer also welcome. Shipping paid. Dr. J. S. Phillips, Child Study Center, University of Denver, Denver, CO 80208.

WANTED: Nonprofit educational institution seeks tax-deductible contribution of an Apple IIe or IIc with printer for class use. Sherrill Jones, Northside Elementary School, Milledgeville, GA 31061, (912) 452-8502.

WANTED: Nonprofit youth-benefitting organization seeks 256K IBM PC, daisy-wheel printer, and public-domain software and/or 256K Apple IIe for business and training use. Will pay shipping and send receipt. John Donohue, San Francisco Youth Sports Travel Fund Inc., POB 31488, San Francisco, CA 94131, (415) 661-5002.

WANTED: Nonprofit after-school day-care center seeks tax-deductible donation of public-domain word-processing and database software for Apple II+. Karen Schiller, Havurah Youth Center, San Francisco Jewish Community Center, 3200 California St., San Francisco, CA 94118, (415) 346-6040, ext. 224.

WANTED: Tax-deductible contributions welcomed by nonprofit organization acting as equipment clearinghouse for many nonprofit organizations needing hardware donations in Montana, Idaho, and Wyoming. Northern Rockies Action Group, 9 Placer, Helena, MT 59601, (406) 442-6615.

WANTED: Nonprofit organization specializing in promoting family life seeks tax-deductible donations of computer equipment to expand services. Marian Redinger, Beginning Family, 14260 Lake Hills Blvd., Bellevue, WA 98007, (206) 644-2207.

WANTED: Tax-deductible donation of TRS-80 computer and peripherals or Kaypro and compatible CP/M machines to support orthodox church group community project. Monastery of St. Justin Martyr, POB 844, El Dorado, CA 95623, (916) 644-6652.

NEEDED: Small church seeks computer system (IBM, Apple, or Commodore) for bookkeeping and word processing. Donations are tax-deductible. Templo El Olivar, POB 729, Sunland Park, NM 88063, (915) 778-8605.

NEEDED: Word-processing and computer equipment to assist nonprofit ministry to preach in all parts of the world. Charles and Yvonne Svitlik, Cornerstone Ministries, POB 845, Waterbury, CT 06720.

WANTED: Nonprofit tax-exempt organization needs donation of IBM PC, Apple, TRS-80, or compatible for general accounting and stock-control applications. Mrs. Z. Elizondo, Confraternity of Christian Doctrine, 276 Pitt St., Sydney, New South Wales 2000, Australia.

WANTED: Nonprofit community service organization seeks tax-deductible donation of Apple or compatible with printer. New Life Foundation, Box 2000, Ojai, CA 93023.

WANTED: Swedish student would like to correspond with others who have an interest in artificial intelligence in general and LISP in particular. Fredrik Nyman, Pilvägen 1, S-616 00 Åby, Sweden.

WANTED: I need to convert my Apple II to a II+, but I can't find the autostart ROMs. Can anyone help? Richard Ashby, M.D., 9713 Old Creek Rd., Ventura, CA 93003, (805) 649-2725 or 652-6153.

WANTED: Information on punch-card readers, including interface for connection to an Apple II+ or CompuPro (S-100) running a Z80 processor. Walter F. George, M.D., 1345 East 14th St., San Leandro, CA 94578, (415) 483-6367.

WANTED: A copy of BYTE document #112 (LISP interpreter for the 6800 or similar document for the 6809). Mark Wilson, POB 14, Huntingdon, PA 16652.

WANTED: Documentation on OEM (parallel) interface Diablo Hi-Type II daisy-wheel printer including pin assignments, voltage levels, etc. Maintenance information also appreciated. Will refund postage costs. Dick Dixon, Ilmarin, Vale View Dr., Beech Hill, Reading RG7 2BD, England.

WANTED: Working Intel 4004 and 8008 microprocessor chips for science museum exhibit. Send price. Ray Albrektson, 900 Edgehill Court, Covington, KY 41011.

WANTED: BYTE, issues 1 through 10. Will pay reasonable price for good condition. Dave Jenson, 7200 Marilyn NE, Albuquerque, NM 87109, (505) 821-0109.

WANTED: Information about sales places of literature for Casio FP-200 notebook computer, particularly on how to create an assembly program and to redefine the character set. Javier Argandoña Lazo, Dr. Johow No. 385, Ñuñoa, Santiago, Chile.

FOR SALE: TI-99/4A, cassette-recorder cable, and books: $130. Timex Sinclair 1000: $20. ColecoVision: $140. Atari 5200: $170. I will pay postage. Heriberto Suarez, Buzon 3034, Trujillo Alto, Puerto Rico 00760.

FOR SALE: DEC PDP-11/05 system with 32K, includes restart/LDR, CRC/LRC arithmetic element, Unibus CTL RK06-EA 120/60, single-access RK06 120/60 Hz, 10½-inch expander box 120 V. DEC maintained. Best offer. Mary Ann Atkins, Fountaindale Public Library District, 300 West Briarcliff Rd., Bolingbrook, IL 60439, (312) 759-2103.

FOR SALE: Radio Shack information distribution network. Five TRS-80 Model II terminals, four disk drives, one MUX. Sue, Data Support Service, 7711 Carondelet 504, Clayton, MO 63015.

FOR SALE: PDP-11/10, two RK05s, Laboratory Peripheral System, VT-52, and manuals. $800. Science Unlimited Research Foundation, 311-D Spencer Lane, San Antonio, TX 78201.

FOR SALE: Complete system board for Columbia 1600-1. 8088 processor, one parallel and two serial ports, power supply, and documentation. $400. Paul Bookbinder, 150 West 87th St., New York, NY 10024, (212) 840-1327.

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FOR SALE: Apple II+ (64K) with two Apple drives, Zenith monitor, Epson MX-80 F/T with graphics chips, RS-232 interface, RF modulator, manuals, and accessories. Excellent condition. $1100. John Lipa, 165 Harcross Rd., Woodside, CA 94062, (415) 366-0547.

WANTED: Commodore 64 and 128 users in U.S. and Canada for public-domain software club. Jonathan Harte, 138 Birch-Hill Dr., Ottawa, Ontario K1K 3Y5, Canada, (613) 746-7392.

FOR SALE: NEC PC-8001A computer, 8031 dual 150K disk drives, Renaissance Technology Wedge, NEC JB1201 monitor, extra RS-232C port, sound synthesizer board, A/D/A ports, Centronics parallel port, and 300-bps modem. $1700. James Bucan, 278 Sisson St., Romeo, MI 48065, (313) 752-2660.

FOR SALE: Dimension 68000, 1-megabyte RAM, four floppy-disk drives, and IBM, Z80, and Apple emulation boards. Asking $6000. Stan Miley, 2812 Hillside Dr., Bryan, TX 77802, (409) 846-1664.

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FOR SALE: Hazeltine Executive 80 Model 20 terminal, 80/132 columns, up to 19,200 bps, character graphics, eight programmable function keys, detachable keyboard. Paul Wick, 10503 Jimenez St., Lake View Terrace, CA 91342, (818) 896-3502.

FOR SALE: Tektronix 60-MHz oscilloscope, Model 2215, dual trace, dual time base, delayed sweep, with manuals, probes, and cover. $1200 or best offer. Richard Gorton, DVI-C68544, POB 600, Tracy, CA 95376.

FOR SALE: Sol-20 48K computer with Micropolis 630K dual drive Model 1053 MOD II, manuals, and more. All in good condition. $750 plus postage. John L. Gorman Sr., 210 Sprague Ave., South Plainfield, NJ 07080.

WANTED: ALSPA ACI-2 CP/M computer. Duncan Moyer, 13418 Garden Bar, Grass Valley, CA 95945, (916) 268-0115.

FOR SALE: BYTE: January 1982, 23 copies will be sold individually by lottery for $5 each. Send SASE for drawing. Selene Pappas, 23644 North 84th St., Scottsdale, AZ 85255.

WANTED: Hewlett-Packard 86/87, 128K memory module, serial (RS-232C) interface, I/O ROM, modem, and plotter ROM. D. Bran, 12335 Santa Monica Blvd. #192, Los Angeles, CA 90025.

FOR SALE: Intersystems S-100 system, 64K, Z80, two serial and two parallel ports, two Shugart 850 DS/DD, C. Itoh 101 terminal, PROM burner, modem, and more. $1400 or best offer. Martin Unger, 1415 Northwest 62nd St., Ft. Lauderdale, FL 33309, (305) 772-3070.

FOR SALE: BYTE: June through December 1976: $20; 1977 through 1983: $30 per year. David Baldwin, 22 Fox Den Rd., Hollis, NH 03049, (603) 465-7857.

FOR SALE: Mannesmann Tally MT-160 printer. Epson-compatible, 160 cps, has near-letter-quality mode. In fine working condition. Asking $200. Also, Apple 80-column card: $25. Dave Schultz, 12801 Countryview Court, Burnsville, MN 55337.

WANTED: EPROM copy, disk copy, source code, or hex dump of operating system for TLC Problem Solver Intelligent Terminal (TOS version 1.011 or later). Also schematics or other documentation. (PSS Inc. out of business in 1979.) Will provide TOS in 2732 for your terminal. Tim Vest, 4 Cambridge Rd., Convent Station, NJ 07961, (201) 993-8541.

WANTED: Correspondence about computers for solar and greenhouse applications. John Wilson, 29001 Harvey Lane, Corvallis, OR 97330.

FOR SALE: Hewlett-Packard 9816 personal computer, 9121 two-drive unit, 82906A dot-matrix printer, and all manuals. Mint condition. W. M. Davidson, 4405 West Pyracantha, Tucson, AZ 85741, (602) 742-3982.

FOR SALE: Cromemco Trace System simulator Model TSS-S, $15. N. Conroy, 177 Tosca Dr., Stoughton, MA 02072, (617) 344-1352. ■

B·O·M·B

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BOMB *Results*

SIMULATION TABULATION

Lawrence Cone wins $100 for his article "Skycam: An Aerial Robotic Camera System," which placed first in the results of October's issue. In second place is the theme "Why Models Go Wrong" by Tom R. Houston, who wins $50. Part 2 of Clifford Kelley's "EGO: A Homebuilt CPU" covering "The Hardware" came in third. Steve Ciarcia, Bruce Webster, and Jerry Pournelle remain popular with readers. Hats off to all.

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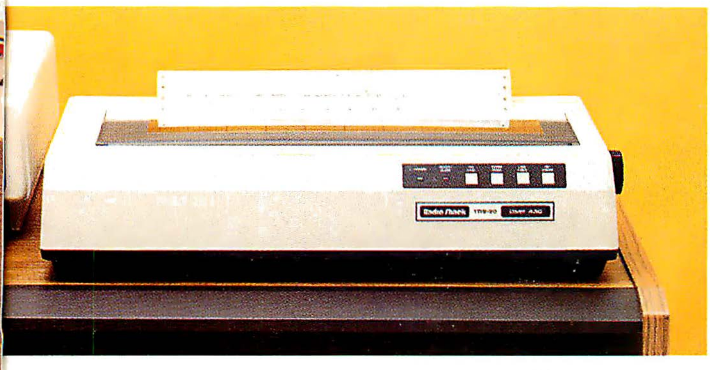
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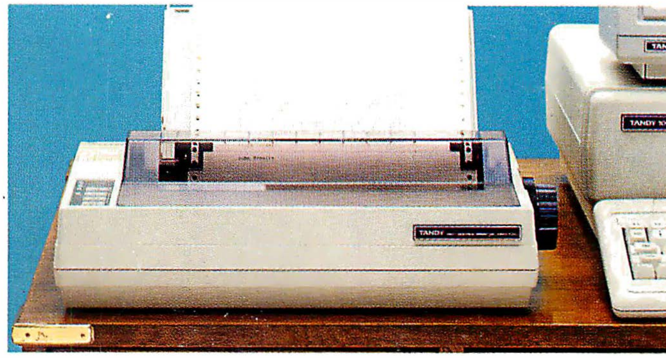
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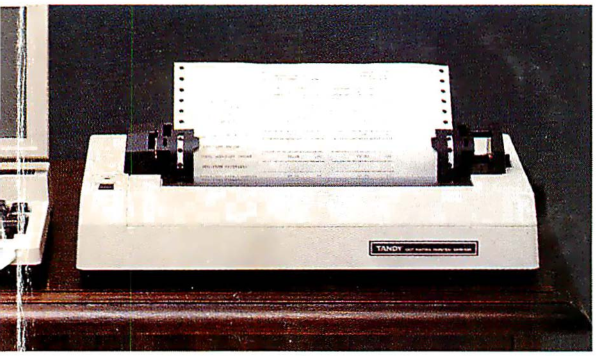
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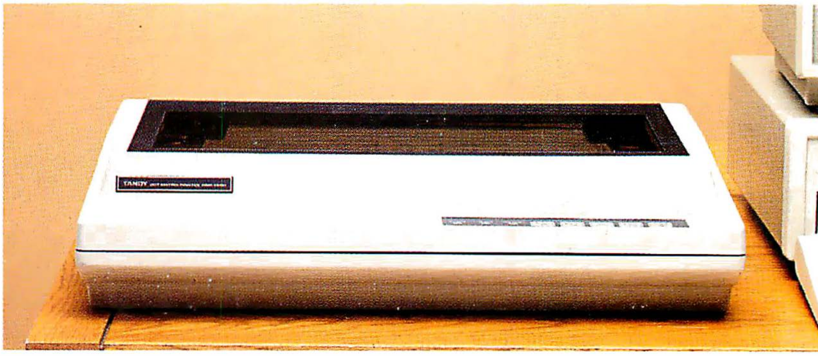
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